SOIL SURVEY OF IOWA

BOONE COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section

Soils

Soil Survey Report No. 34

April, 1924

Ames, Iowa

10-11-79

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April, 1924 Soil Survey Report No. 34

SOIL SURVEY OF IOWA

Report No. 34--BOONE COUNTY SOILS

By W. H. Stevenson and P. E. Brown with the assistance of L. W. Forman, A. M. O'Neal, and A. M. Deyoe.

Typical farmstead in Boone county.

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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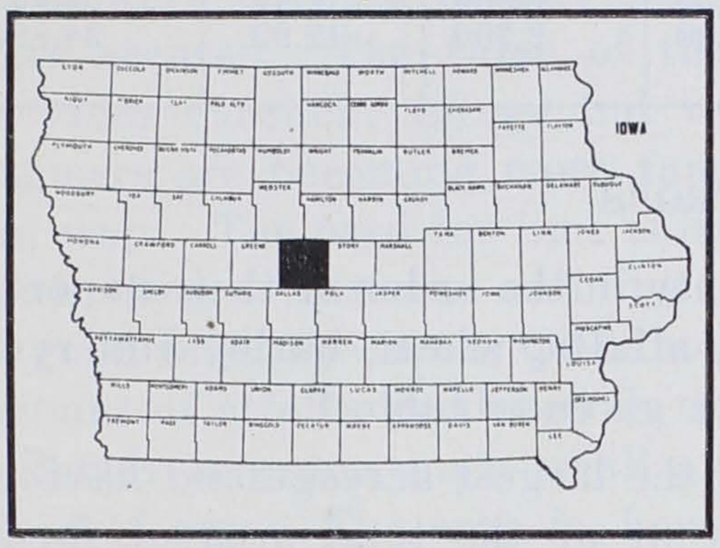
BOONE COUNTY SOILS*

By

W. H. Stevenson and P. E. Brown with the assistance of L. W. Forman, A. M. O'Neal, and A. M. Deyoe

BOONE COUNTY is located in central Iowa almost in the center of the state. The location is shown on the accompanying sketch map. It lies entirely in the Wisconsin drift soil area and hence its soils are all of glacial origin. The total area of Boone county is 569 square miles or 364,160 acres. Of this area 343,709 acres, or 94.3 percent is in farm land. The total number of farms is 2,481 and the average size of the farms is 139 acres.



The following figures taken from the Iowa Year Book of Agriculture for 1921 show the utilization of the farm land of the county:

Acreage in general farm crops	241,538
Acreage in pasture	78,521
Acreage in farm buildings, feed lots and public highways	16,166
Acreage in waste land	2,960
Acreage in crops not otherwise listed	257

The type of agriculture practiced in the county at the present time is mainly livestock farming. There is some general farming and on most livestock farms there is some sale of grain. The livestock industry includes mainly the raising and feeding of cattle and hogs. The dairy industry is developing to some extent but is of minor importance. Sheep raising is also practiced somewhat and on practically all farms the production of poultry and poultry products is becoming of considerable significance.

A considerable acreage in the county is still in waste land, some of which at least, might be reclaimed and made productive thru proper methods of soil treatment. There are areas which certainly might be utilized for pasture if they were properly handled. General recommendations cannot be given for the reclamation of waste land as the causes of infertility are too variable. Sometimes the only treatment needed is adequate drainage. Sometimes protection from erosion may be of the most importance. In many cases, however, special methods of cropping and soil treatment must be practiced. In a later section of this report recommendations will be made regarding the methods which should be followed in the handling of individual soils, which will include suggestions for the reclamation of waste areas. In special cases, where the conditions are abnormal the Soils Section of the Iowa Agricultural Experiment Station will offer suggestions regarding desirable treatments.

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*Soil Survey of Boone County, Iowa, by A. M. O'Neal of the U. S. Department of Agriculture and A. M. Deyoe of the Iowa Agricultural Experiment Station.

TABLE I. ACREAGE, YIELD AND VALUE OF CROPS GROWN IN BOONE COUNTY, IOWA*

Crop	Acres	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price	Total value of crops
Corn	130,000	37.82	46.0	5,980,000	$ 0.30	$1,794,000
Oats	84,000	24.43	24.0	2,016,000	0.23	463,680
Spring wheat	350	0.10	11.0	3,850	0.87	3,349
Winter wheat	700	0.20	19.0	13,300	0.90	11,970
Barley	540	0.15	25.0	13,500	0.42	5,670
Rye	50	0.01	17.0	850	0.73	620
Potatoes	598	0.17	73.0	43,649	1.40	61,108
Tame hay	19,000	5.52	1.40	26,600	9.08	241,528
Wild hay	5,400	1.57	1.29	6,966	7.47	52,036
Alfalfa	900	0.26	3.00	2,700	12.92	34,884
Pasture	78,521	22.84				

BOONE COUNTY'S CROPS

The general farm crops grown in Boone county in the order of their importance are as follows: corn, oats, hay, potatoes, alfalfa, wheat, barley and rye. The acreage, yield and value of these crops are given in table I.

Corn is the most important crop, occupying the largest acreage and having the greatest value. It occupies over 37 percent of the total area of farm land in the county and in 1921 average yields amounted to 46 bushels per acre. In favorable seasons on better soils the corn yields are higher. The major portion of the crop, estimated at from 75 to 85 percent, is used on the farms for fattening beef cattle and hogs and for feeding dairy and work stock. The remainder is sold and shipped out of the county. The amount utilized on the farms is increasing annually as the livestock industry increases. Considerable amounts of the corn produced are used for silage and in 1921 there were 235 silos in the county. Some of the corn products are cut for forage purposes. Dent corn is grown almost exclusively, Reid's Yellow Dent being the most popular variety. A few farmers raise white corn, Boone County White, Silver Mine and Silver King.

The oat crop is second in acreage and value in the county. Almost one-fourth of the total area of land was in oats in 1921, when average yields amounted to 24 bushels per acre. On some of the soils under favorable seasonal conditions the yields are very much higher. This crop is grown extensively in the county largely because it fits in well in the rotation with the corn crop. Practically all of the oats produced are used for feeding purposes on the farm for beef cattle, hogs, dairy cattle and work stock. Only a small portion is sold to the local elevators. The varieties of oats most commonly grown and most satisfactory in this county are Iowar, Iowa 105 and Iowa 103.

The hay crop is third in importance. Timothy and clover constitute the most important hay crop and average yields amount to 1.4 tons per acre. The crop is generally seeded with the oats as a nurse crop and after the second year consists mainly of timothy. Some red clover is grown alone and in some instances is utilized chiefly for seed. There is a small area of wild hay, yields of 1.29

*Iowa Yearbook of Agriculture, 1921.

tons per acre being secured. The hay produced is all utilized for feed on the farms and additional amounts must frequently be purchased.

Potatoes are grown on practically all farms, in most instances the crop being utilized for home consumption. In 1921, 43,649 bushels of potatoes were produced with an average yield of 73 bushels per acre.

Wheat growing is practiced to some extent but the area devoted to this crop is very much smaller than formerly. Winter wheat was grown somewhat more extensively in 1921 than the spring varieties and the average yield was somewhat greater. At the present time the small amount of wheat produced is used entirely on the farms.

The growing of alfalfa is constantly becoming more general. In 1921, 900 acres were devoted to this crop and average yields of three tons per acre were secured. The value of this crop is considerable, not only because it provides excellent forage but because it improves the fertility of the soil. Farmers are becoming more familiar with methods of seeding and handling the crop. The need for lime is important and inoculation should be practiced. With these treatments and the preparation of a good seed bed and the use of good seed, success is quite common in the growing of alfalfa. The entire amount of alfalfa produced in the county is used for feed on the farms.

Barley is grown on a small area, sometimes being used in the rotation in place of oats. The crop is, however, of minor importance and where grown is utilized for feeding purposes.

Rye is grown only to a small extent and is relatively of little importance. Sorghum is raised on a number of farms, syrup being made for home use and sold on the local markets.

Sweet clover is grown to some extent, the crop being utilized for forage purposes. Soybeans are becoming more generally grown and are being used mainly for ensilage. Occasionally the crop is used for pasturing hogs. Sweet corn, buckwheat and millet are other crops of minor importance. Some rape is grown and used for hog pasture. On some of the sandy areas in the county watermelons and muskmelons are grown.

Apple orchards are maintained on most of the farms but the yields are not generally large. The fruit grown is all utilized for home consumption.

BOONE COUNTY'S LIVESTOCK BUSINESS

The livestock industry of the county includes the raising and fattening of beef cattle and hogs, dairying, sheep raising and feeding and raising of horses.

The following figures taken from the Iowa Yearbook of Agriculture for 1921 show the extent of the livestock industry of the county:

Horses (all ages)	12,823
Mules (all ages)	966
Swine (on farms July 1, 1921)	77,704
Swine (on farms January 1, 1922)	53,766
Cattle (cows and heifers kept for milk)	10,518
Cattle (other cattle not kept for milk)	23,905
Cattle (total, all ages, January 1, 1922)	34,423
Sheep (all ages)	2,557
Sheep (shipped in for feeding)	1,358
Sheep (total pounds of wool clipped)	9,842
Poultry (total number on farms January 1, 1922)	330,093
Poultry (number of dozen eggs received 1921)	1,263,929

The raising and feeding of beef cattle is a very important industry. On most farms some beef cattle are raised and herds of from 10 to 40 are quite generally found. The most popular breed is the Shorthorn, tho there are some herds of Aberdeen Angus and Hereford. There are from 30 to 35 breeders of pure bred stock in the county. The practice of feeding cattle is quite general, the feeders being commonly secured in the Omaha and Sioux City markets.

The raising of hogs is practiced quite generally thruout the county and some are found on every farm. Poland China, Duroc Jersey, Chester White and Hampshire are the most common breeds. In some seasons hogs are bought and shipped in for feeding. Most of the hogs produced are sold on outside markets.

Dairying is practiced to some extent and provides considerable income for some farmers. In 1921 there were 10,518 cows kept for milk.

A few horses are kept on every farm and many farmers raise a few horses each year for their own use.

There are a few permanent flocks of sheep in the county but most of the sheep are shipped in each year for fattening. The amount of wool produced has increased in the last few years and in 1921 there was a clip of 45,689 pounds. The feeder sheep are generally turned into the corn fields in the fall and then fed for a few months before being sold.

Poultry raising is becoming a more important industry, providing considerable income on many farms. Flocks are maintained on practically every farm, but in many cases they are given little attention. The poultry and eggs produced are sold locally or to commercial houses.

VALUE AND CONDITION OF BOONE COUNTY LAND

Land values in Boone county are extremely variable, being determined by the soil conditions, topography, location with reference to towns and railroads and by the improvements on the farms. At the time of the survey in 1920 prices ranged from $250 to $400 per acre, averaging about $325. There are some areas of less agricultural value and for this land the price would be somewhat lower, but the average as given would probably be fairly accurate at the present time.

Average yields of general farm crops grown in Boone county at the present time are very satisfactory, but larger crops might be secured on many areas by the adoption of better methods of handling the soils. In some instances drainage is not adequate and when that is true, the best crop yields cannot be secured. Other treatments are of little value on soils which are too wet, and thoro drainage of many soils in Boone county, should be provided.

Boone county soils are all acid and satisfactory yields of crops, particularly of legumes, cannot be secured until lime has been applied. In some cases the lower soil layers are well supplied with lime, but where the surface soil is acid, additions are very necessary in order to secure good stands of legumes. The soils will vary widely in lime requirements and tests should be made in every soil before legumes are seeded.

The content of organic matter and nitrogen in the soils of the county is fairly adequate in most cases, but the supply must be maintained for continued fertility. Applications of farm manure prove of large value on all soils, even on those where the supply of organic matter is apparently not low. The increases in crops secured from the use of the manure are always profitable. Crop residues should be thoroly utilized and there are undoubtedly instances where leguminous crops might be utilized as green manures with distinct value. Large applications of farm manure are not desirable on the level upland soils of the Webster series, but small amounts prove of value. On these types the manure should not be applied preceding the small grain crop owing to the danger of causing it to lodge. On the more rolling areas where the soils are lighter in color applications of manure should be made regularly to keep up the fertility.

The supply of phosphorus in Boone county soils is low and phosphorus fertilizers will undoubtedly be needed in the near future even if they are not essential at the present time. Some evidence has been obtained experimentally and by farm experience to show that phosphates may often be employed now with profitable effects. Whether rock phosphate or acid phosphate should be used must be determined for individual farms. It is urged that farmers test the need of phosphate on their soils and at the same time determine which material will prove more desirable for use. This can be accomplished by simple field experiments which can be carried out on any farm.

Some erosion occurs in the county, but except for the steep phase of the Clarion loam there is not any extensive washing of the soils. On the more rolling portions of the Carrington and Clarion loams, small gullies are occasionally found and sheet erosion sometimes occurs. Wherever erosion is found, care should be taken to prevent any serious washing away of the soil.

THE GEOLOGY OF BOONE COUNTY

The rock formations underlying the soils of Boone county have been so deeply buried by deposits of glacial material that it is not necessary to consider the geology of the county in any detail.

At least twice during the glacial age enormous masses of debris known as glacial till, or drift, were deposited over the county when the glaciers retreated. The early topographic features were largely obliterated by the grinding action of the glaciers, which brought about the filling up of old valleys and the leveling of old elevations. The depth of the two drift deposits is somewhat variable over the county, averaging about 100 feet. In the northeastern part the deposit varies from 60 to 120 feet in thickness; near the city of Boone it is 200 feet thick, at Ogden 110 feet. In other parts of the county the drift may be only 50 to 60 feet in depth.

The earlier deposit of glacial till, known as the Kansan, was deeply covered by a later deposit and none of the soils in the county are derived from it. It is occasionally exposed in road cuts, but in practically all instances it is so far below the surface that it does not affect the agricultural character-

istics of the various types. This lower till deposit averages about 40 feet in thickness, grading from the more oxidized yellow material in the exposed portions down to the unoxidized blue clay of the original drift.

The entire county was covered during the more recent glacial age with the later deposit of till which is known as the Wisconsin. It varies in thickness from 40 to 90 feet. It is composed of a mass of clays, sands, gravels and boulders. In its unoxidized condition it is grayish-blue in color and in the lower depth this original color still prevails. Toward the surface oxidation has occurred and the drift is yellow to yellowish-brown from depths varying from 10 to 40 feet. Boulders are commonly found on the surface and the soils formed from the Wisconsin deposit are characterized by their content of pebbles, gravel and small boulders. In most cases calcareous concretions are found within the three foot soil section. In the other cases lime is not found except at extreme depths.

Since the deposition of this glacial material upon the retreat of the Wisconsin ice sheet, the soils have been formed under varying topographic conditions. Drainage conditions and the character of the vegetation which prevailed in local areas have led to the differentiation of various soil types. On the level, poorly drained prairie areas, the Webster soils have been formed and are characterized by a black color, the result of intensive accumulation of vegetation residues. On the more rolling areas with better drainage the Carrington and Clarion soils have developed. They are dark in color but much lighter than the Webster series. Plant food has been washed away to a larger extent and there has been less accumulation of vegetation residues. The Conover soils have been developed on the forested upland areas, rolling to rough in topography, and have but little accumulation of organic matter and even smaller amounts of plant constituents. These soils are very light in color.

The terrace and bottomland soils have been deposited by the streams and are made up of material washed down from the uplands. They are composed therefore of drift material but their characteristics vary widely depending on the method of formation.

PHYSIOGRAPHY AND DRAINAGE

The topography of the greater part of Boone county is level to gently rolling, as there has not been any large modification of the surface features since the retreat of the Wisconsin ice sheet. Other flat, poorly drained areas, with small low knolls rising occasionally in them, occur quite commonly thruout the greater part of Grant, Des Moines, Jackson and Garden townships. In the northeastern part along the Hamilton county line there are more pronounced topographic features which are evidenced in the morainic hills and ridges. These higher areas are largely composed of the Clarion fine sandy loam. There are also rather striking topographic features rising above the less sharply rolling areas of Carrington loam which are interspersed with level areas of Webster silty clay loam and Webster loam.

Along the Des Moines river which passes thru the county from north to south, almost in the center, the relief is quite pronounced and there are

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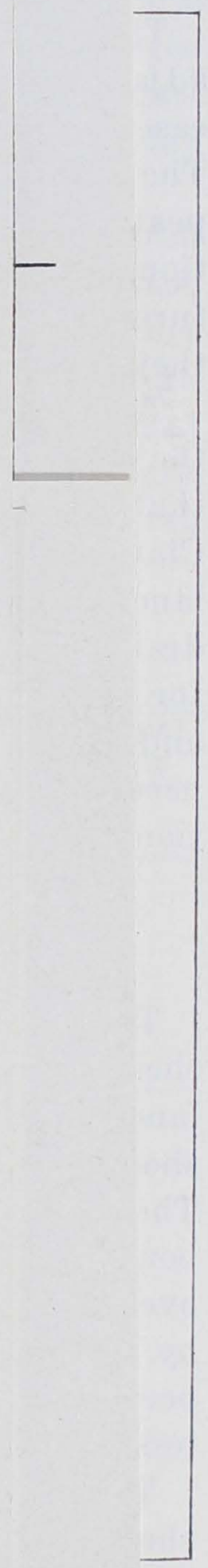

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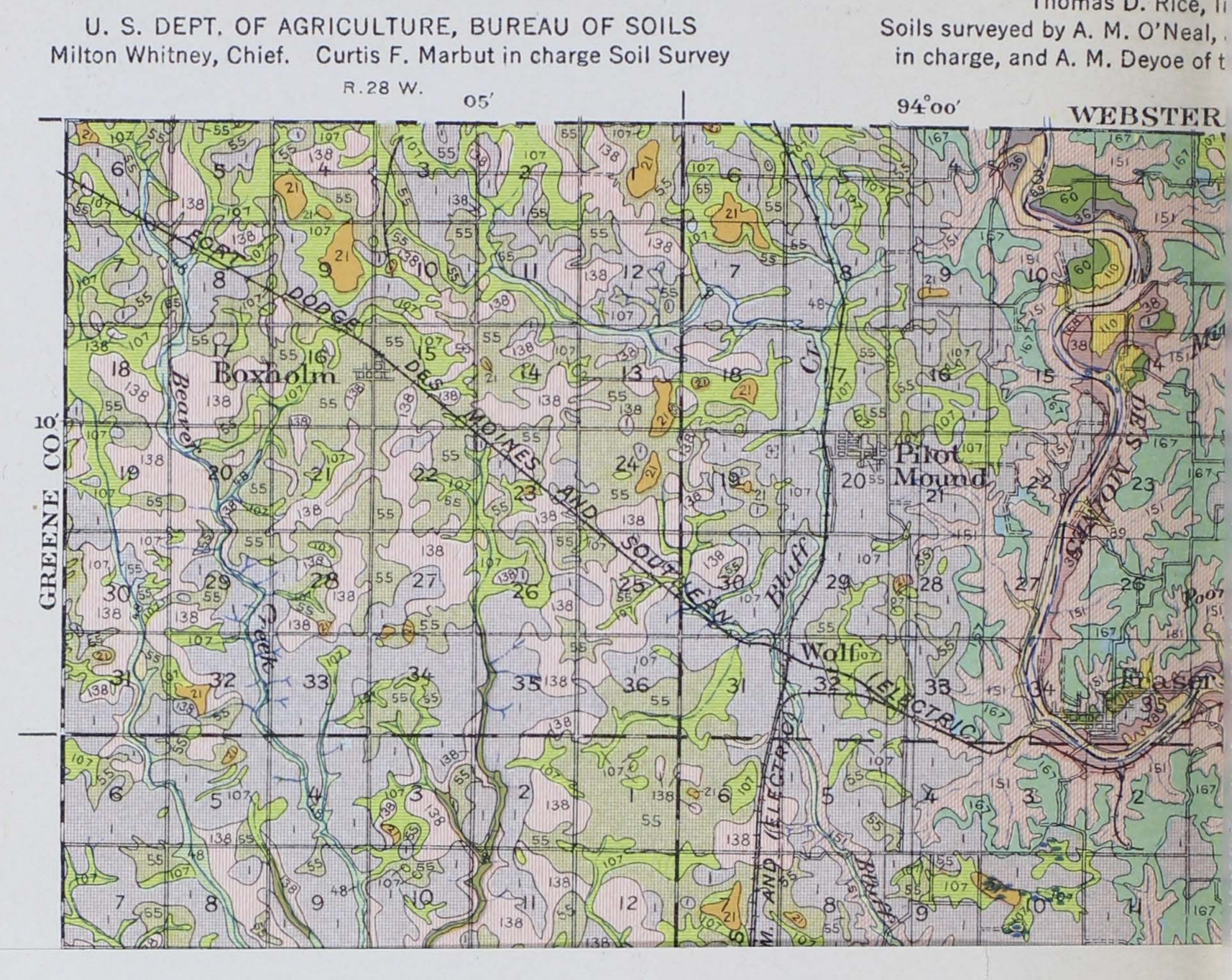
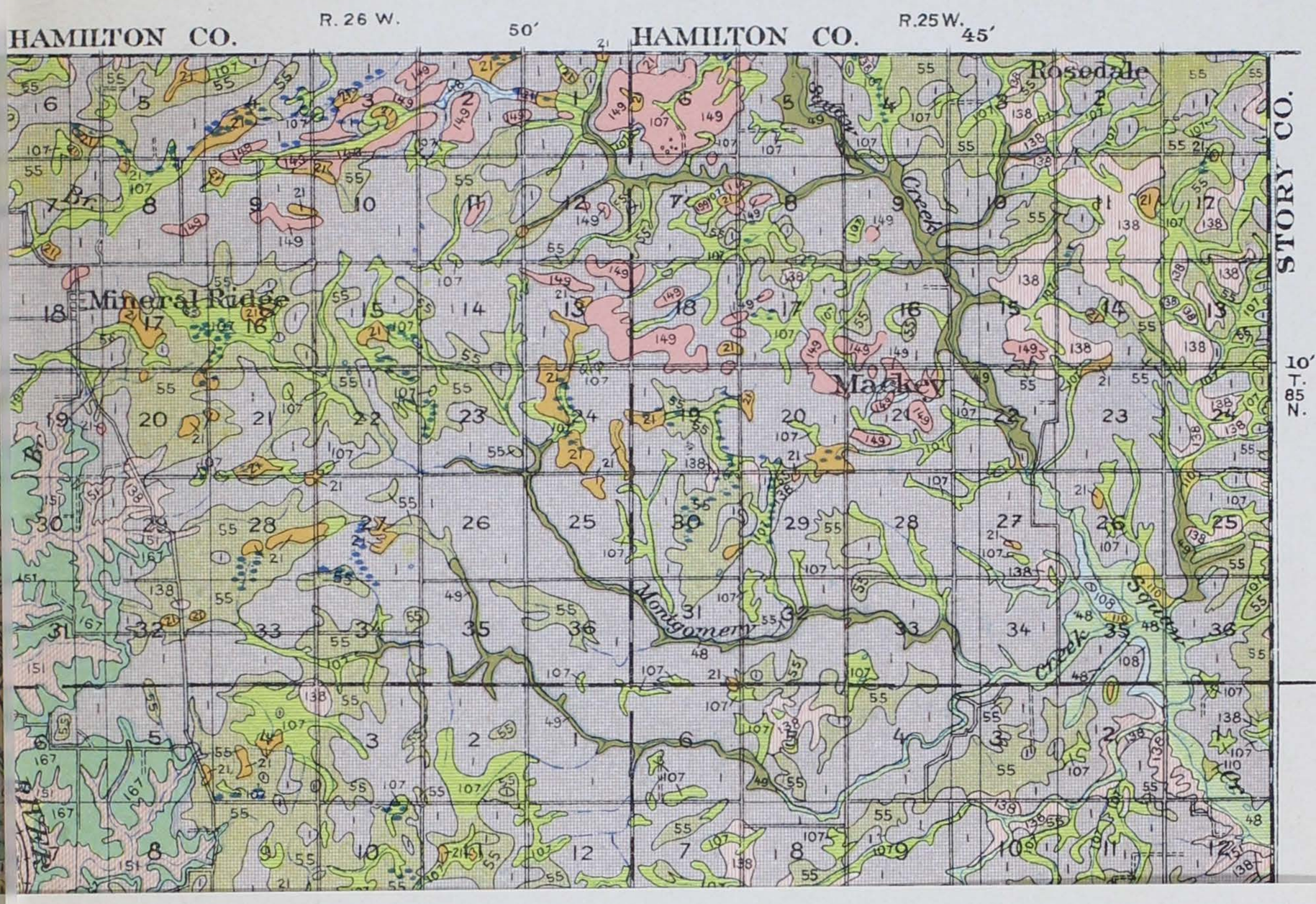


OONE COUNTY

r, Northern Division.
he U. S. Department of Agriculture,
a Agricultural Experiment Station.

IOWA AGRICULTURAL EXPERIMENT STATION
C. F. Curtis, Director. W. H. Stevenson, in charge Soil Survey
P. E. Brown, Associate in charge.



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SOIL MAP OF BOONE COUNTY

U. S. DEPT. OF AGRICULTURE, BUREAU OF SOILS
Milton Whitney, Chief. Curtis F. Marbut in charge Soil Survey

Thomas D. Rice, Inspector, Northern Division.
Soils surveyed by A. M. O'Neal, Jr., of the U. S. Department of Agriculture, in charge, and A. M. Deyoe of the Iowa Agricultural Experiment Station.

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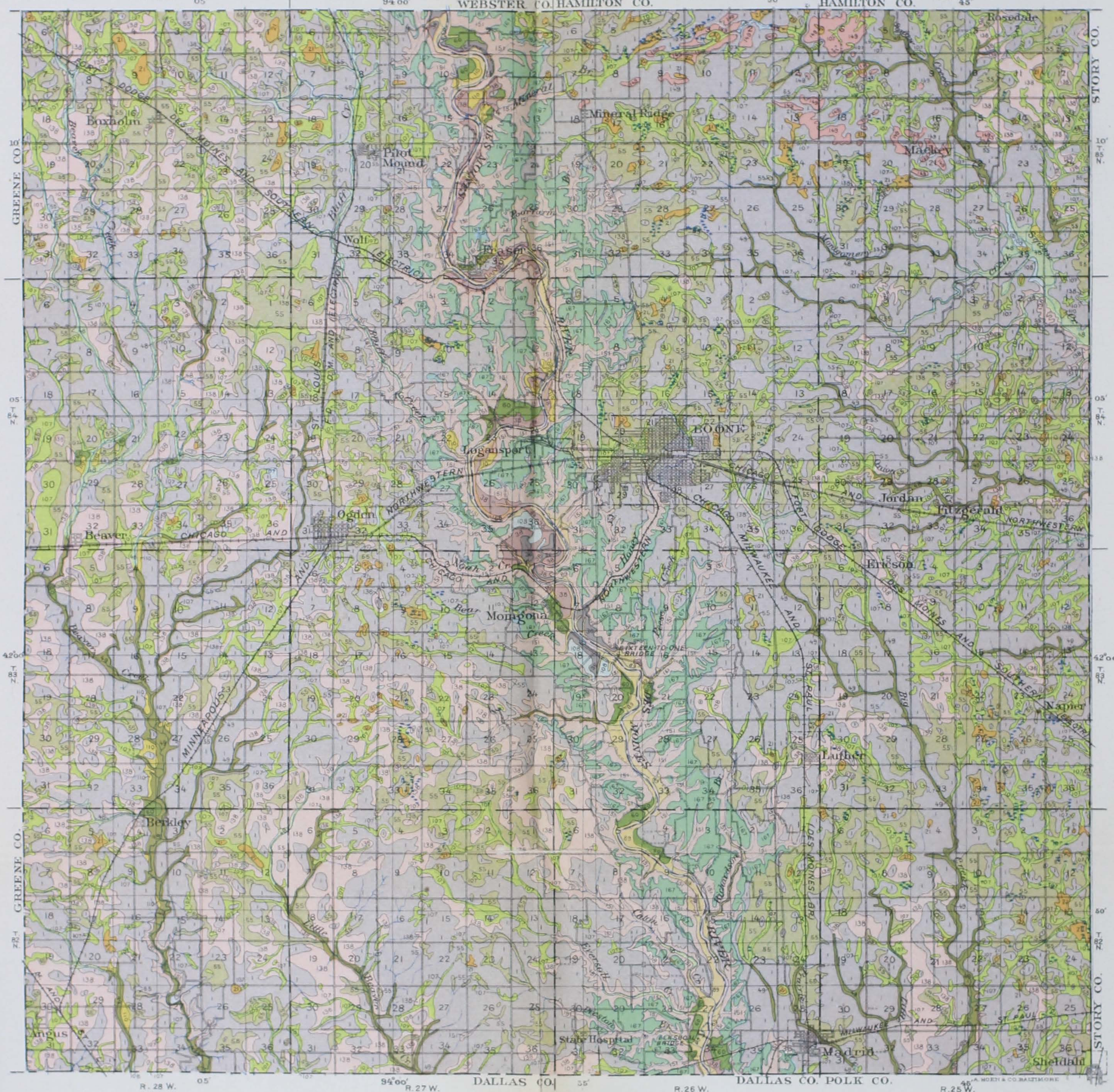

LEGEND

DRIFT SOILS

- Carrington loam
- Clarion loam
- Clarion loam (steep phase)
- Webster loam
- Webster silty clay loam
- Conover silt loam
- Clarion fine sandy loam

TERRACE SOILS

- Buckner loam
- Waukesha loam
- O'Neill fine sandy loam
- O'Neill loam
- Buckner silt loam
- Buckner loamy fine sand

SWAMP AND BOTTOMLAND SOILS

- Wabash loam
- Wabash silty clay loam
- Peat and Muck
- Sarpy silt loam

Scale: 1 inch=2½ miles

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extensive areas of steep phase Clarion loam, Conover silt loam and Carrington loam bordering the stream which show quite rough topographic features. Thruout the remainder of the county, where the surface is gently rolling to flat, the soil types include the Carrington loam and Clarion loam on the more rolling areas. These are separated into small individual areas by the level Webster loam and Webster silty clay loam soils. There are no large continuous areas of any of these types.

The Des Moines River flows thru a deep narrow valley and the topography on both sides may be described as gently rolling to rough and broken. These steeper slopes may extend from one to three miles back from the stream following the channels of the tributary creeks.

There are narrow areas of terraces along the river and some of the larger creeks. Strips of bottomland are found along the various streams in the

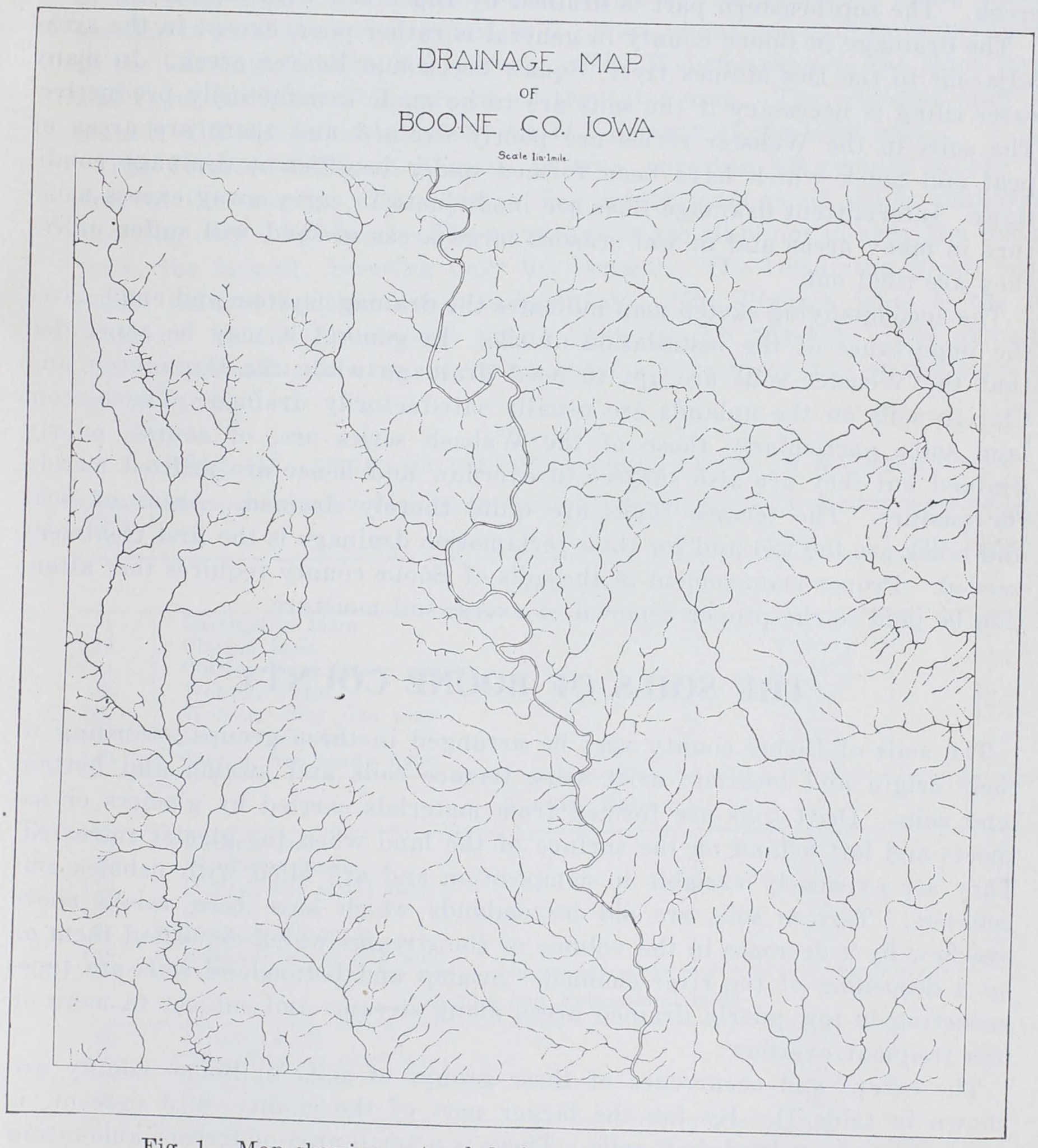

Fig. 1. Map showing natural drainage system of Boone county.

county and they are mostly extremely narrow, the largest area being developed along Squaw creek in the northeastern part.

The general slope of the county is toward the south and the drainage flows in that direction. The Des Moines river with its tributaries affords most of the drainage. The chief tributary streams are Bluff creek, Honey creek, Richardson branch, Caton creek and Eversoll creek. The tributary streams with their sources occupy broad shallow areas and often have poorly defined channels. As they approach the Des Moines river the channels become deeper and narrower and the topography rougher. Along the river itself the valley is 130 to 250 feet below the level of the prairie upland. The drainage of the northeastern part of the county is brought about by Squaw creek and its tributaries, chief of which are Montgomery creek and Prairie creek. The western part is drained by Beaver creek and its tributaries and little Beaver creek. The southeastern part is drained by Big creek with its tributaries.

The drainage in Boone county in general is rather poor, except in the areas adjacent to the Des Moines river, Squaw creek and Beaver creek. In many cases tiling is necessary if the soils are to be made satisfactorily productive. The soils in the Webster series are poorly drained and there are areas of peat and muck which have been formed under insufficient drainage conditions. Intermittent drainage lines are inadequate to carry away excess moisture in many areas and in wet seasons large areas of land will suffer unless they are tiled out.

The accompanying sketch map indicates the drainage system and emphasizes the importance of the installation of tile. In general it may be concluded that the Webster soils are apt to need drainage while the Carrington and Clarion soils on the uplands are usually satisfactorily drained. The bottom land soils, particularly those of the Wabash series are, of course, poorly drained but they are also subject to overflow and hence are utilized merely for pasture. The terrace types are quite thoroly drained. Areas of peat and muck are too wet and for their reclamation drainage is the first treatment needed. Proper management of the soils of Boone county requires that attention be paid to the proper removal of excess soil moisture.

THE SOILS OF BOONE COUNTY

The soils of Boone county may be arranged in three groups according to their origin and location, drift soils, terrace soils and swamp and bottom land soils. Drift soils are formed from materials carried by glaciers or ice sheets and left behind on the surface of the land when the glacier retreated. They are extremely variable in composition and are filled with pebbles and boulders. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams which deposited them or by a deepening of the river channel. Swamp and bottomland soils are those occurring in low poorly drained areas along streams and subject to more or less frequent overflow.

The extent and occurrence of these groups of soils in Boone county are shown in table II. By far the larger part of the county, 93.3 percent, is covered by the upland drift soils. There is a small area of terrace amounting

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN BOONE COUNTY

Soil group	Acres	Percent of total area of county
Drift soils	339,840	93.3
Terrace soils	6,592	1.9
Swamp and bottomland soils	17,728	4.8
Total	364,160	

to 1.9 percent and the bottomlands are somewhat larger, covering 4.8 percent of the total area.

There are fifteen soil types and these together with the steep phase of the Clarion loam and an area of peat and muck make a total of 17 separate soil areas. The areas of the different soil types are shown in table III. The Carrington loam is the most extensive individual type, covering 40.4 percent of the total area. The Clarion loam, together with the steep phase which is smaller in area than the typical soil, covers about one-half as large an area as the Carrington loam, 20.1 percent. The Webster loam is the third largest soil type, covering 16.3 percent of the total area. The Webster silty clay loam is still less extensive, covering 11.1 percent of the total area.

The Conover silt loam is small in area, covering 4.9 percent of the total area of the county. The Clarion fine sandy loam is of minor importance, covering only 0.5 percent. The terrace soils are all minor in area, the Buckner loam, the largest, covering only 0.6 percent. The remaining types are all minor in area and relatively unimportant. The Wabash loam is the most extensive of the bottomland types, covering 1.9 percent. The remaining types are smaller in area, covering about 1 percent or less of the total area of the county.

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN BOONE COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
	Drift Soils		
1	Carrington loam	147,264	40.4
138	Clarion loam	48,384	20.1
151	Clarion loam (steep phase)	24,832	
55	Webster loam	59,520	16.3
107	Webster silty clay loam	40,512	11.1
167	Conover silt loam	17,664	4.9
149	Clarion fine sandy loam	1,664	0.5
	Terrace Soils		
38	Buckner loam	2,176	0.6
60	Waukesha loam	1,536	0.4
110	O'Neill fine sandy loam	1,344	0.4
108	O'Neill loam	704	0.2
36	Buckner silt loam	640	0.2
168	Buckner loamy fine sand	192	0.1
	Swamp and Bottomland Soils		
49	Wabash loam	6,976	1.9
48	Wabash silty clay loam	4,160	1.1
21	Peat and muck	3,520	1.0
89	Sarpy silt loam	3,072	0.8
	Total	364,160	

As has been noted there are distinct relationships between the individual soil types and the topographic features of the county. The Carrington and Clarion soils are characteristically rolling in topography. The steep phase Clarion is of course extremely rough and the Conover silt loam occurs on rather level to gently undulating uplands along the Des Moines river. The terrace soils are quite level in topography and the bottomland soils are flat to depressed. The relation of the topographic features of the individual soil types to the drainage needs of the county have been noted.

THE FERTILITY IN BOONE COUNTY SOILS

Samples were taken for analysis from each of the types found in Boone county. The area mapped as peat and muck was not sampled, as it is small in extent, individually variable in character and not very important agriculturally. Many analyses have been made of peat and muck and the composition of these materials is very similar, hence it seemed unnecessary to analyze samples from this county. The more extensive soil types were sampled in triplicate. With the minor types, however, only one sample was taken. The samplings were all made with the greatest care so that the results would show clearly the conditions in the particular soil type and that variations in composition due to unusual local conditions or previous soil treatments should be eliminated.

The samples were taken at three depths, 0 to 6 2/3 inches, 6 2/3 to 20 inches, and 20 to 40 inches, representing the surface soil, subsurface soil and subsoil respectively. Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The usual methods were employed in the phosphorus, nitrogen and carbon determinations and the Truog qualititative test was used in determining the lime requirement. The figures given in the tables are the averages of the results of duplicate determinations on all samples of each type, and they represent therefore, the averages of four or twelve determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of two million pounds of surface soil per acre.

The phosphorus content of the various soil types in the county is extremely variable, ranging from 633 pounds in the Conover silt loam up to 1,736 pounds in the Buckner loam. There seems to be no relationship between the amount of phosphorus in the soil groups, the bottomland soils showing only a slightly higher content on the average than the upland types. The terrace soils will average slightly higher than the upland soils. The growth of crops has of course been much less on the bottomland soils. The variations in phosphorus content are not large within the various groups but there seems to be a certain relationship between the series. Thus the Webster soils are higher than the Carrington and Clarion types and the Conover soils are low in phosphorus. The Buckner and Waukesha soils are higher than the O'Neill types on the terraces, and the surface soils are better supplied than the Sarpy type on the bottoms. These relations are due in large part to the topographic features of the particular soil series. The level, poorly drained Webster soils are

TABLE IV. PLANT FOOD IN BOONE COUNTY, IOWA, SOILS

Pounds per acre of two million pounds of surface soil (0-6 2/3″)

Soil No.	Soil type	Phosphorus	Nitrogen	Organic carbon	Inorganic carbon	Limestone requirement
	Drift Soils					
1	Carrington loam	1,041	3,706	45,420	0	6,333
138	Clarion loam	969	3,680	44,772	0	2,000
151	Clarion loam (steep phase)	969	2,040	24,133	0	4,000
55	Webster loam	1,077	4,960	70,215	0	3,000
107	Webster silty clay loam	1,185	8,680	112,858	0	2,000
167	Conover silt loam	633	2,160	22,713	0	8,000
149	Clarion fine sandy loam	1,010	1,720	20,420	0	3,000
	Terrace Soils					
38	Buckner loam	1,736	5,080	64,646	0	4,000
60	Waukesha loam	1,266	4,920	51,870	0	2,000
110	O'Neill fine sandy loam	942	4,600	51,433	0	6,000
108	O'Neill loam	1,212	2,680	37,837	0	7,000
36	Buckner silt loam	1,642	4,560	56,565	0	2,000
168	Buckner loamy fine sand	1,723	3,360	43,789	0	2,000
	Swamp and Bottomland Soils					
49	Wabash loam	1,293	9,080	78,078	0	2,000
48	Wabash silty clay loam	1,549	8,480	94,840	0	2,000
89	Sarpy silt loam	1,279	2,800	48,211	0	2,000

higher in phosphorus than the more rolling upland types. There are also, of course, characteristics of the soil series which affect the phosphorus supply. Thus the soils which are darker in color and heavier in texture contain more phosphorus than light colored light textured types.

It is not possible from the data available in this county to draw any definite conclusions regarding the relation between soil texture and the phosphorus supply, as there are not enough types of the same series to permit of conclusive results. The Wabash silty clay loam seems to be higher than the loam. The Webster silty clay loam is higher than the loam of the same series. The O'Neill loam is higher than the fine sandy loam. The types of the Buckner series are all about the same in phosphorus content and give no evidence of any relationship to texture. It does seem, however, that heavy textured types are richer in plant food constituents than coarse textured soils, and the variations in phosphorus supply may be traced in many cases to the texture of the particular soils.

It seems evident from these analyses that phosphorus is not abundant in any of the soils in Boone county. In some cases the supply is far too low to provide all that would be needed for the best crop growth. In those cases where the supply is somewhat better there is no evidence that the phosphorus is being changed into an available form rapidly enough to supply the needs of crops. In all cases, therefore, an addition of a phosphorus fertilizer may be very desirable at the present time. No doubt phosphorus must be supplied to these soils in the future in any case, as the total content is insufficient to last for any extended period of time. Farmers may easily determine

for their own conditions whether or not phosphorus fertilizers will prove of value by carrying out simple tests on small areas.

The nitrogen content of Boone county soils is somewhat variable, ranging from 1,720 pounds per acre in the Clarion fine sandy loam up to 9,080 pounds in the Wabash loam. No relationships are apparent between the nitrogen supply and the various soil groups altho the average of the bottomlands is naturally somewhat higher than the average of the uplands. Some interesting relations are shown, however, between the nitrogen content and the various soil series; thus the Webster soils are higher than the Carrington, Clarion or Conover types. The Wabash soils are much higher than the Sarpy types, and the Buckner and Waukesha soils will average higher than the O'Neill types.

The topographic condition is an important factor, as is evidenced by the higher content of nitrogen in the Webster soils compared with the more rolling upland types. The color is also an important factor in the separation of soil series and thus bears a definite relation to nitrogen; the light colored types are poorly supplied with this element. Differences in texture will also affect the nitrogen content as is evident in some of the types in Boone county. Thus the Webster silty clay loam is higher in nitrogen than the loam; the Buckner loam is higher than the other types of the same series; the Clarion loam is better supplied than the fine sandy loam. Occasionally textural differences may be the controlling factor, but in most cases other factors are of more significance. In general it may be concluded that fine textured types are better supplied with nitrogen than coarse textured soils.

In general it seems that the soils of the county are rich in nitrogen, but in some instances the amount present is obviously insufficient. In all cases, however, nitrogen must be considered in planning systems of permanent fertility. Soils lose nitrogen continuously by drainage and the growing of crops, and some fertilizer supplying this element must be applied if the content is to be kept up.

Farm manure is an important nitrogenous fertilizer as it returns to the land a large part of the nitrogen removed from the soil by growing crops. Applications should be made regularly on all soils to aid in keeping up the nitrogen supply. On heavy textured darker soils, which are richer in this element, small applications only are necessary and the manure should not be applied preceding the small grain crop of the rotation owing to the danger of causing it to lodge. On light colored types larger amounts may be applied with distinct profit, and are indeed necessary as in such cases its use is necessary not only to increase the nitrogen content of the soils but also to keep up the supply.

Well inoculated legumes used as green manures are a second means which may be employed to increase and keep up the nitrogen in soils. On the grain farm green manuring is a necessity as no farm manure is produced, but it is often desirable also on the livestock farm to supplement the farm manure. Legumes have the ability when well inoculated to draw upon the nitrogen from the atmosphere and hence when they are turned under in the soil they may increase the amount of this constituent considerably. The turning under of all crop residues in the soil also aids materially in keeping up the nitrogen

supply. These materials should never be wasted, as they are important in permanent fertility.

The amount of organic carbon in soils indicates the supply of organic matter. The color of the soil likewise indicates the amount of organic matter present and hence there is usually a rather distinct relationship between soil color and the content of organic carbon. But there is also a relation between color and nitrogen content. Black soils are high in organic matter and high in nitrogen, while light colored types are low in both constituents. The color of the soils in Boone county varies considerably and hence as might be expected there are wide differences in organic carbon as well as in nitrogen content. The amount of organic carbon ranges from 20,420 pounds in the Clarion fine sandy loam up to 112,858 pounds in the Webster silty clay loam. These types showed likewise the lowest and highest amount of nitrogen respectively.

In general the relationship between the various soil types and the organic carbon is about the same as in the case of nitrogen. Thus the Webster soils of the upland are higher than the Clarion and Carrington types. Similarly, the latter soils are better supplied than those of the Conover series. Among the terrace soils the Buckner and Waukesha types average higher than the O'Neill soils, and on the bottoms the Wabash types are richer than the Sarpy soils. The relationships between organic carbon and texture are likewise very similar to those noted in the cases of nitrogen. The silty clay loams are higher than the loams; this is seen in the case of the Webster and Wabash soils. The Buckner loam is higher than the silt loam and the latter is better supplied than the loamy fine sand. The Clarion loam is much better supplied than the fine sandy loam. Apparently fine textured types are much better supplied than coarse textured soils. The topographic position, origin and previous history of the soil also effect the organic matter content just as was true in the case of nitrogen. Level, poorly drained soils, heavy in texture and developed under prairie conditions are higher in organic carbon, and blacker in color than rolling types or those developed under forested conditions.

The relation between the organic carbon and the nitrogen in soils indicates the rate at which plant food constituents are made available. If the relation is not satisfactory plants may suffer from a lack of a proper supply of food material. In most of the soils of Boone county the relationship is such that it would seem that available plant food is being produced sufficiently rapidly to supply crop needs. In one or two cases, however, the relationship is not at the best. In the Conover, silt loam, the Waukesha loam, the Clarion fine sandy loam and the O'Neill fine sandy loam it would be very desirable to stimulate a more rapid production of available plant food. In these cases applications of farm manure are of particularly large value, because of the effect of the manure in bringing about a more rapid production of available food.

Farm manure should be applied, however, not only to these types mentioned, but to all the soils of the county, if the content of organic matter and nitrogen is to be maintained. On the Webster soils small applications may be used with profit and large amounts should not be applied preceding the small grain crop. On all other types in the county, however, larger applications may be made with desirable effects. In general, eight to ten tons per acre

TABLE V. PLANT FOOD IN BOONE COUNTY, IOWA, SOILS

Pounds per acre of four million pounds of subsurface soil (6 2/3″—20″)

Soil No.	Soil type	Phosphorus	Nitrogen	Organic carbon	Inorganic carbon	Limestone requirement
	Drift Soils					
1	Carrington loam	1,975	5,760	66,757	0	5,000
138	Clarion loam	1,778	5,120	60,278	0	2,000
151	Clarion loam (steep phase)	2,424	2,840	24,024	0	3,000
55	Webster loam	1,696	6,320	78,296	0	2,000
107	Webster silty clay loam	2,396	4,800	72,157	4,600	0
167	Conover silt loam	1,076	2,160	22,932	0	7,000
149	Clarion fine sandy loam	1,778	2,400	24,897	0	3,000
	Terrace Soils					
38	Buckner loam	3,124	7,440	91,072	0	4,000
60	Waukesha loam	1,642	4,160	44,553	0	2,000
110	O'Neill fine sandy loam	1,966	6,000	63,663	0	7,000
108	O'Neill loam	1,818	2,240	31,668	0	5,000
36	Buckner silt loam	2,990	6,320	77,750	0	2,000
168	Buckner loamy fine sand	2,666	4,960	51,374	6,502	0
	Swamp and Bottomland Soils					
49	Wabash loam	1,588	4,480	56,565	0	2,000
48	Wabash silty clay loam	2,532	4,480	115,642	0	2,000
89	Sarpy silt loam	1,912	2,320	38,159	26,768	0

is the normal application. All crop residues should be utilized along with the farm manure as a means of keeping up the supply of organic matter and nitrogen, and on the grain farm green manuring must be practiced, if farm manure is not produced. By thoro utilization of all crop residues, all farm manure produced and a turning under of leguminous crops as green manures, it is possible to maintain the organic matter and nitrogen content in the soils of the county, under any system of farming.

The soils of Boone county show no content of inorganic carbon in the surface soil and hence it is evident that the soils are acid in reaction and in need of lime. The amount of lime required is indicated in the table. The figures given should be taken, however, merely as indicative of the needs of the individual soil types. Samples should always be secured from the particular field before lime is applied, as wide variations occur in the amount of acidity in soils. The analyses reported in the table merely indicate that the soils of the county are quite generally acid and lime should be applied if the best growth of crops, particularly of legumes, is to be expected. Large increases in crop yields are secured from the use of lime on acid soils, and frequently the success or failure of clover or alfalfa will depend on the application of lime. The soils should be tested at regular intervals and lime applied when necessary for continued fertility. Probably a test once in the four-year rotation just preceding the seeding of clover and the application of lime, if necessary at that time, is the most desirable practice.

THE SUBSURFACE SOILS AND SUBSOILS

The result of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4,000,000 pounds of

subsurface soil and 6,000,000 pounds of subsoil per acre. The lower soil layers in Boone county do not show any large content of the essential plant food constituents and in most cases the supply decreases from the surface soil. There will be little effect, therefore, on the fertility of the surface soil, and the needs will be indicated quite definitely by the analyses of the surface samples. The analyses of the lower soil layers therefore need not be considered in detail. It may merely be noted that they serve to confirm conclusions reached in the discussion of the surface soil analyses. They show the need for phosphorus fertilizers, if not at the present time certainly in the near future. They show that the content of organic matter and nitrogen must be maintained and in some cases increased, if the fertility of the soil is to be kept up.

Lime occurs in considerable amounts in some of the soils at lower depths, small amounts occurring in the subsurface of the Webster silty clay loam, the Buckner loamy fine sand and the Sarpy silt loam. The subsoil of these types is also high in lime and considerable amounts are found in the subsoils of the Clarion loam, Webster loam and the Clarion fine sandy loam. The fact that lime is present in the subsoils of these types indicates that it will not be so difficult a matter to keep these soils supplied with lime. Lime rarely moves upward in the soil and hence the amount in the subsoil will not keep up the supply in the surface soil. On the other hand lime is gradually washed out of the soil and the supply continually decreases. It is important, therefore, that the soils be tested for lime requirements at regular intervals if legume growth and continued fertility is to be entirely satisfactory.

TABLE VI. PLANT FOOD IN BOONE COUNTY, IOWA, SOILS

Pounds per acre of six million pounds of subsoil (20″—40″)

Soil No.	Soil type	Phosphorus	Nitrogen	Organic carbon	Inorganic carbon	Limestone requirement
	Drift Soils					
1	Carrington loam	2,343	4,000	53,889	0	3,666
138	Clarion loam	1,705	2,400	23,943	146,409	0
151	Clarion loam (steep phase)	2,988	2,160	22,851	89,352	0
55	Webster loam	1,980	3,240	36,677	5,583	0
107	Webster silty clay loam	3,312	2,760	34,110	37,470	0
167	Conover silt loam	2,058	2,520	35,544	0	4,000
149	Clarion fine sandy loam	2,667	1,800	10,019	2,868	0
	Terrace Soils					
38	Buckner loam	3,636	4,320	54,545	0	3,000
60	Waukesha loam	2,100	3,720	33,251	0	3,000
110	O'Neill fine sandy loam	2,058	4,680	54,217	0	5,000
108	O'Neill loam	2,988	1,440	14,742	0	4,000
36	Buckner silt loam	4,200	5,400	71,253	0	2,000
168	Buckner loamy fine sand	3,030	2,760	31,268	24,096	0
	Swamp and Bottomland Soils					
49	Wabash loam	1,656	2,160	30,630	0	2,000
48	Wabash silty clay loam	2,625	6,120	123,996	0	2,000
89	Sarpy silt loam	3,393	4,800	55,174	48,183	0

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Boone county in order to secure some information regarding their fertilizer needs and the possible value of the application of certain fertilizing materials. These experiments were carried out on the Carrington loam and the Webster loam, two of the most important types in the county. In addition to these experiments the results of similar tests on the Clarion loam from Palo Alto county, and the Webster silty clay loam and the Carrington loam from Wright county are included, inasmuch as these soils occur extensively in Boone county and the results are undoubtedly applicable to conditions in the latter county.

The treatments used include manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. These materials were employed in the same amounts in which they are applied in the field experiments and in practice, and hence the results secured may be considered quite definitely indicative of what may occur in the field.

Manure was added at the rate of eight tons per acre and lime in sufficient amounts to neutralize the acidity of the soil and supply two tons additional. Rock phosphate was used at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a standard 2-8-2 brand of a complete commercial fertilizer at the rate of 200 pounds per acre. Wheat and clover were grown in all the plots, the clover being seeded about one month after the wheat was up. In some of the experiments only the clover yields are given and in others only the wheat yields were secured.

RESULTS ON CARRINGTON LOAM

The results obtained in the experiment on the Carrington loam from Boone county are given in table VII, only the average yields from the duplicate plots being shown. The yield of wheat on one pot in this test was not secured. Manure gave a considerable increase in the yields of both the wheat and clover. The results from the use of lime are not definite. Rock phosphate showed a distinct effect on the wheat crop and a rather considerable influence on the clover. Acid phosphate and the complete commercial fertilizer had less effect on the wheat than the rock phosphate, but in the case of the clover crop extremely large increases were secured with both materials, the increases being far ahead of that brought about by the rock phosphate.

It seems evident that manure is of considerable value for use on this soil and applications of a phosphate fertilizer may also prove distinctly profitable. Rock phosphate seemed to show better results on the wheat, while acid phosphate was far superior on the clover. The complete commercial fertilizer

TABLE VII. GREENHOUSE EXPERIMENT. CARRINGTON LOAM, BOONE COUNTY

Pot	Treatment	Wt. wheat grain in grams	Wt. clover in grams
1	Check	7.95	23.0
2	Manure	8.64	32.0
3	Manure+lime	....	31.0
4	Manure+lime+rock phosphate	9.67	37.0
5	Manure+lime+acid phosphate	9.47	50.0
6	Manure+lime+complete commercial fertilizer	9.21	57.0

Fig. 2. Greenhouse experiment on Carrington loam.

was not as effective as the acid phosphate on the wheat but was slightly more effective on the clover. Apparently definite conclusions regarding the use of rock phosphate or acid phosphate on this soil should not be drawn until more definite results are secured. Lime frequently proves beneficial on this type, according to field experiments, altho the results in this test were not definite.

RESULTS ON WEBSTER LOAM

Table VIII gives the results secured on the Webster loam from Boone county. Only the wheat yields are given in this table. No results were obtained for the clover crop. Little effect was evidenced on this soil from the application of the manure or the lime, altho there were slight increases in the wheat yields. This type is high in organic matter and usually also in lime so large effects from manure and lime would not be expected. Rock phosphate gave a small increase but acid phosphate brought about a very distinct gain in the wheat. The complete commercial fertilizer was only a little better than the rock phos-

TABLE VIII. GREENHOUSE EXPERIMENT, WEBSTER LOAM, BOONE COUNTY

Pot	Treatment	Total wheat grain in grams
1	Check	8.90
2	Manure	9.19
3	Manure+lime	9.45
4	Manure+lime+rock phosphate	9.90
5	Manure+lime+acid phosphate	14.03
6	Manure+lime+complete commercial fertilizer	10.21

Fig. 3. Greenhouse experiment on Webster loam.

phate and did not give as large effects as the acid phosphate. There are indications that applications of phosphate may prove distinctly profitable on this type. Small applications of manure are often valuable and lime should be used when the soil type is acid, which is not often the case.

RESULTS ON CLARION LOAM (PALO ALTO COUNTY)

The results secured on the Clarion loam from Palo Alto county are given in table IX. In this test manure showed large increases in both the wheat and clover crops. Lime had no additional effect. Rock phosphate increased both crops showing a rather distinct increase on the clover. Acid phosphate gave the same yield as the rock phosphate in the case of wheat but brought about a much larger influence on the clover. The complete commercial fertilizer was not of any more value on the wheat than the phosphates and showed even less effect on the clover. Evidently on this type manure is a valuable fertilizer and should be used quite generally. Lime may be necessary in some cases

TABLE IX. GREENHOUSE EXPERIMENT, CLARION LOAM, PALO ALTO COUNTY

Pot No.	Treatment	Wt. wheat grain in grams	Wt. clover in grams
1	Check	9.5	56.69
2	Manure	14.5	68.04
3	Manure+lime	14.0	68.04
4	Manure+lime+rock phosphate	16.0	74.84
5	Manure+lime+acid phosphate	16.0	86.18
6	Manure+lime+complete commercial fertilizer	16.3	70.25

TABLE X. GREENHOUSE EXPERIMENT, WEBSTER SILTY CLAY LOAM, WRIGHT COUNTY

Pot No.	Treatment	Weight green clover in grams
1	Check	61.23
2	Manure	108.86
3	Manure+lime	127.00
4	Manure+lime+rock phosphate	140.61
5	Manure+lime+acid phosphate	131.54
6	Manure+lime+complete commercial fertilizer	124.74

altho it did not show effects in this particular experiment. There are indications of profit from the use of phosphate and acid phosphate seems somewhat preferable, particularly for clover. The complete commercial fertilizer did not show larger effects than the phosphates and hence could not be recommended for use unless special tests are carried out to demonstrate the value.

RESULTS ON WEBSTER SILTY CLAY LOAM (WRIGHT COUNTY)

In table X the results secured on the Webster silty clay loam from Wright county are given. In this test only the green weights of the clover were secured. On this soil manure gave a large increase in the clover crop and the lime in addition to manure gave a further considerable increase. Both the rock phosphate and the acid phosphate when added with lime and manure increased the clover yield, the rock phosphate showing up somewhat better than the acid phosphate. The complete commercial fertilizer had less effect than either of the phosphates. Evidently this soil will respond to light applications of manure and should be limed when acid in the surface soil, especially if clover is to be grown. The use of a phosphorus fertilizer is very desirable and may prove distinctly profitable on this type. Whether rock or acid phosphate should be employed must be determined for the individual farm conditions.

RESULTS ON CARRINGTON LOAM (WRIGHT COUNTY)

The results secured on the Carrington loam from Wright county are given in table XI. In this test also only the green weights of the clover are recorded. The application of manure showed a large effect on the clover yield. Lime had little influence. The phosphates both increased the yield considerably, the acid phosphate giving the larger increase. The complete commercial fertilizer showed up better than the acid phosphate but it is doubtful if the increase was sufficient to pay for the increased cost of the application. These results checked closely with those given in table VII for the Carrington

TABLE XI. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, WRIGHT COUNTY

Pot No.	Treatment	Weight green clover in grams
1	Check	68.04
2	Manure	108.86
3	Manure+lime	104.32
4	Manure+lime+rock phosphate	113.40
5	Manure+lime+acid phosphate	122.47
6	Manure+lime+complete commercial fertilizer	138.34

loam from Boone county. They indicate the value of applying manure and phosphates to this soil. Lime often proves of value on this type altho it did not in this test. Whether rock phosphate or acid phosphate should be employed in the field must be determined by individual conditions as the tests given are not definite enough to permit of conclusions. It seems doubtful if a complete commercial fertilizer would prove as desirable on this soil as the use of acid phosphate.

FIELD EXPERIMENTS

A field experiment has been started in Boone county but thus far results have not been secured and no data is available. This field test will be carried on for a period of years and the results secured will be published later in a supplementary report. Several experiments in other counties, located on some of the soil types which occur most extensively in Boone county, give results which may undoubtedly be considered to indicate rather definitely the results which may be secured in Boone county. The same fertilizers would undoubtedly yield very similar results if applied to the same soil types in this county.

These field tests include the Truesdale field on the Carrington loam in Buena Vista county, the Lundgren field on the Webster loam in Webster county, the Newell field and the Storm Lake field, on the Webster silty clay loam, both in Buena Vista county. These fields are all located on land which is thoroly representative of the individual soil types. Corner stakes are installed to show the location of the plots which were 155 feet 7 inches by 28 feet in size, covering 1/10 of an acre. Care is used in the application of fertilizer, harvesting crops and securing yields so that the results obtained are as accurate as it is possible to secure.

On each field tests are carried to determine the value of manure, lime, rock phosphate, acid phosphate and a complete commercial fertilizer under the livestock system of farming. Additional tests are under way on many of the fields using crop residues instead of manure representing the grain system of farming. In the data given in this report no results under the grain system of farming are included, owing to the fact that the crop residue treatment has not been completely carried out. Manure is applied at the rate of eight tons per acre once in a four year rotation. Limestone is added when necessary in an amount sufficient to neutralize the acidity of the soil and supply two tons additional. Rock phosphate is applied at the rate of 2,000 pounds per acre once in the rotation, acid phosphate at the rate of 200 pounds per acre annually, and a standard 2-8-2 complete commercial fertilizer at the rate of 300 pounds per acre annually. In 1923 the complete fertilizer brand was changed to the new 2-12-2 fertilizer and this is now being employed on these plots at the rate of 267 pounds per acre annually, supplying an amount of phosphorus equivalent to that in the 200 pounds of acid phosphate.

In addition to these individual results from various experimental fields a table is given showing the average yields of various crops grown on all the experiment fields in the state on the Carrington loam. Yields of corn, oats, and clover are given. The corn yields are the averages of 20 crops from 10 fields, the oats are the average from 9 crops on 5 fields, the clover from

TABLE XII. FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY

Truesdale Field—Series I

Plot No.	Treatment	Corn bu. per acre 1918	Corn bu. per acre 1919	Oats bu. per acre 1920	Clover tons per acre 1921	Corn bu. per acre 1922
1	Check	38.9	56.5	57.2	1.40	48.6
2	Manure	44.3	57.1	57.9	1.20	61.6
3	Manure+lime	46.4	58.1	59.2	1.60	64.0
4	Manure+lime+rock phosphate	54.4	58.7	64.7	2.45	63.2
5	Manure+lime+acid phosphate	49.6	58.7	64.9	3.30	61.6
6	Manure+lime+complete commercial fertilizer	49.6	58.7	64.7	3.10	63.7
7	Check	38.4	58.1	56.4	2.20	51.0

15 crops on 9 fields. In this table the results are given for the crop residue or grain system plots as well as for the manure or livestock system plots. These average results serve to confirm quite definitely the indications obtained from the experiments on the individual fields, and they indicate therefore what may be expected from similar treatments in the field.

THE TRUESDALE FIELD

The results obtained in series I on the Truesdale field located on the Carrington loam in Buena Vista county, are given in table XII. Manure brought about an increase in all the crops except the clover in 1921, the largest increase being evident on the corn in 1922. Lime increased the yields in all cases, showing the largest effect on the clover, as would be expected. Rock phosphate gave increases in most years, the largest effect being shown on the oats and on the clover. In the case of the corn the increases were generally smaller and in 1922 no increase at all was secured. Acid phosphate gave very similar increases to the rock phosphate except in the case of clover and with that crop very much larger yields were secured by the use of acid phosphate. The complete commercial fertilizer showed gains which were very similar to those brought about by the phosphates, giving however less effect than the acid phosphate on the clover. It would seem from these tests that manure should prove of value on this soil and phosphate fertilizers may often prove profitable.

Table XIII gives the results obtained on Series II on the Truesdale field, the crop yields having been secured in this series for three years. Again manure increased the yields of corn and oats, showing particularly large

TABLE XIII—FIELD EXPERIMENT, CARRINGTON LOAM, BUENA VISTA COUNTY

Truesdale Field—Series II

Plot No.	Treatment	Corn bu. per acre 1920	Corn bu. per acre 1921	Oats bu. per acre 1922
1	Check	47.5	32.8	18.5
2	Manure	57.0	39.7	24.6
3	Manure+lime	59.0	41.8	27.2
4	Manure+lime+rock phosphate	61.2	38.1	32.4
5	Manure+lime+acid phosphate	62.1	40.1	31.0
6	Manure+lime+complete commercial fertilizer	64.0	44.4	31.9
7	Check	57.1	36.2	23.6

TABLE XIV—FIELD EXPERIMENT, WEBSTER LOAM, WEBSTER COUNTY

Lundgren Field

Plot No.	Treatment	Corn bu. per acre 1919	Corn bu. per acre 1920	Oats bu. per acre 1921	Corn bu. per acre 1922
1	Check	59.0	63.8	32.9	57.7
2 & 3	Manure	59.4	63.8	35.3	55.7
4	Manure+rock phosphate	61.3	69.3	38.7	57.1
5	Manure+acid phosphate	65.1	67.2	35.8	54.9
6	Manure+complete commercial fertilizer	65.1	74.2	36.6	57.5
7	Check	54.0	59.7	32.6	46.6

effects on the oats. Lime gave small increases in these crops. Rock phosphate and acid phosphate and the complete commercial fertilizer all gave increases except in one instance. There were no large gains, however, from any of these materials. The complete fertilizer seemed somewhat better than the phosphates. The differences, however, were too small to permit of definite conclusions. The acid phosphate seemed preferable to the rock phosphate but again the results were too nearly alike to prove definite. In general the results of the experiment confirm those secured in series I in the same field, indicating that value of manure and lime and the possible profit to be secured from the use of a phosphorus fertilizer.

THE LUNDGREN FIELD

The results obtained on the Webster loam on the Lundgren field in Webster county are given in table XIV. This soil was not acid in reaction and hence no lime was employed. The manure had little effect on this soil, as might be expected. The phosphates gave small increases on most of the crops and there was little choice between the two materials. The complete commercial fertilizer was very little superior to the phosphates. There are indications from this test that a phosphorus fertilizer may be used profitably on this soil, but tests should be carried out in the field under the particular farm conditions, using both rock phosphate and acid phosphate before either material is applied to any considerable area.

THE NEWELL FIELD

Table XV gives the results secured on the Webster silty clay loam on the Newell field in Buena Vista county. On this soil manure gave increases in the various crops grown in spite of the fact that the type is well supplied with organic matter. Lime had little effect as might be expected from the fact that the soil is not generally acid in reaction and even if the surface soil is slightly acid the subsurface soil and subsoil are generally well supplied with lime. The rock phosphate and acid phosphate both gave increases in crop yields with one exception. The acid phosphate gave a much larger effect on the oats and in some years on the corn. The differences in some cases, however, were not very distinct. The complete commercial fertilizer showed a slightly greater influence on the clover than the acid phosphate but had less effect on the oats and in two instances had less effect on the corn. It would seem that this material is possibly of less value on this type than the acid phosphate. The indications point to the desirability of the use of small

TABLE XV—FIELD EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY

Newell Field

Plot No.	Treatment	Corn bu. per acre 1918	Corn bu. per acre 1919	Oats bu. per acre 1920	Clover 2d cutting lbs. per acre 1921	Corn bu. per acre 1922
1	Check	69.0	44.8	56.7	1,050	68.7
2	Manure	70.9	49.1	64.1	1,200	70.5
3	Manure+lime	71.4	54.4	63.5	1,400	69.9
4	Manure+lime+rock phosphate	74.1	61.4	69.7	1,400	74.1
5	Manure+lime+acid phosphate	66.9	65.1	76.3	2,250	80.0
6	Manure+lime+complete commercial fertilizer	66.4	70.9	68.9	2,400	74.4
7	Check	60.9	62.4	59.4	1,150	66.9

amounts of manure on this type, lime when necessary and the application of acid phosphate or rock phosphate.

THE STORM LAKE FIELD

Table XVI gives the results obtained on the Webster silty clay loam on the Storm Lake field in Buena Vista county. Again manure gave some increases showing up particularly in the case of the clover. Lime had little effect except on the clover, but did show a gain in that crop. Rock phosphate gave increases on the oats and corn but had no effect on the clover. Acid phosphate gave greater increases on the corn and oats than the rock phosphate except in the case of the oats in 1918. Quite a large difference in the corn crop was obtained in 1920. The acid also showed a distinct increase in clover. The complete commercial fertilizer gave slightly greater effects than the acid phosphate in two instances, but was somewhat less effective in the other cases. The results would generally confirm those secured on the Newell field in showing the value of manure and the possible profit to be secured from the application of a phosphorus fertilizer. The indications are that acid phosphate may be of more value than the rock phosphate, but actual tests in the field must be carried out before definite conclusions can be drawn. Lime gives results on this soil when it is acid, especially in the case of a legume crop.

TABLE XVI—FIELD EXPERIMENT, WEBSTER SILTY CLAY LOAM, BUENA VISTA COUNTY

Storm Lake Field

Plot No.	Treatment	Corn bu. per acre 1919	Oats bu. per acre 1918	Corn bu. per acre 1920	Oats bu. per acre 1921	Clover tons per acre 1922
1	Check	73.0	54.7	48.2	45.1	0.75
2	Manure	73.0	54.7	57.3	42.1	1.01
3	Manure+lime	73.0	57.6	58.1	...	1.29
4	Manure+lime+rock phosphate	80.6	61.1	64.2	43.8	1.26
5	Manure+lime+acid phosphate	74.5	66.4	76.5	51.7	1.42
6	Manure+lime+complete commercial fertilizer	82.0	61.1	80.0	43.8	1.43
7	Check	70.0	...	66.6	40.9	1.10

TABLE XVII—AVERAGE CROP YIELDS AND INCREASE DUE TO FERTILIZER TREATMENT ON CARRINGTON LOAM

Iowa Experiment Fields

Treatment	Corn*		Oats*		Clover*	
	Av. yield bu. per acre	Increase for treatment bu. per acre	Av. yield bu. per acre	Increase for treatment bu. per acre	Av. tons per acre	Increase for treatments tons per acre
Check	51.9	....	43.6	....	1.25	....
Manure	58.8	6.9	49.6	6.0	1.38	0.13
Manure+lime	62.6	10.7	53.0	9.4	1.57	0.32
Manure+lime+rock phosphate	66.0	14.1	62.3	18.7	1.97	0.72
Manure+lime+acid phosphate	66.3	14.4	60.8	17.2	2.27	1.02
Manure+lime+complete commercial fertilizer	66.8	14.9	62.4	18.8	2.29	1.04
Crop residues	54.7	2.8	47.3	3.7	1.37	0.12
Crop residues+lime	57.5	5.6	49.3	5.7	1.41	0.16
Crop residues+lime+rock phosphate	61.8	9.9	51.2	7.6	1.80	0.55
Crop residues+lime+acid phosphate	62.4	10.5	52.7	9.1	1.94	0.69
Crop residues+lime+complete commercial fertilizer	64.2	12.3	58.2	14.6	2.02	0.77

*Corn yields averaged from 20 crops on 10 fields, oats from 9 crops on 5 fields and clover from 15 crops on 9 fields.

AVERAGE RESULTS ON THE CARRINGTON LOAM

Average results obtained from all the field experiments in the state on the Carrington loam are given in table XVII. The check or untreated plot averages are calculated from the yields on the three check plots in each field, 1, 7, and 13, and averages struck from the check yields on all the fields. Rather definite evidence is supplied in this table to show the value of applications of various fertilizers to this soil, and as a large number of fields are represented and many crop yields are included, the results may be considered quite conclusive.

The application of manure showed a distinctly beneficial effect on the corn, oats and clover. Lime with manure gave very distinct increases in all cases, the results being quite as definite on the corn and oats as on the clover. Rock phosphate with manure and lime proved of value on all the crops and acid phosphate showed very similar increases on the corn and oats but proved distinctly superior on the clover. The complete commercial fertilizer gave increases in the corn and oat yields which were very similar to those brought about by the phosphates, and in the case of the clover showed an effect very similar to that of the acid phosphate. The crop residues showed little effect on any of the crops. Lime again gave difinite increases in all cases. The rock phosphate and acid phosphate both increased the yields of all the crops, the acid phosphate proving superior to the rock in all cases. The complete commercial fertilizer showed larger effects on all the crops than did the phosphates, but the differences were not large enough to warrant the use of the higher priced material.

These average figures confirm those obtained on the individual fields reported earlier, and bear out the conclusions that the Carrington loam will

respond profitably to applications of manure, lime and phosphorus. Acid phosphate seems to be superior to the rock under the grain system of farming and also shows larger effects on the clover in the livestock system. Tests on the individual farm are necessary, however, if that material is to be used which will give the most desirable effects under any particular conditions. Complete commercial fertilizers are apparently less desirable than the phosphates, inasmuch as they are more expensive and do not bring about crop increases which are consistently greater than those obtained by the use of the phosphorus carriers.

PEAT SOILS

Boone county has several areas of peat soils, comprising with the muck soil a total of 3,520 acres, and they furnish a special problem.

Peat is partially rotted vegetable matter, which consists either of swamp grass, sedges, rushes and flags or of sphagnum moss; the former variety is known as grass peat and the latter as moss peat. Peat forms in swamps, marshes, or flat, undrained areas where water stands and water-loving grasses and mosses grow in profusion. The remains of such plants accumulate under water and the absence of air permits of only very incomplete decomposition. Deposits of peat thus formed increase from year to year and, with long continuance of swampy conditions, may become of considerable depth.

When the glacier which once covered north central Iowa retreated, the rather level Wisconsin drift soil area was left. Numerous depressions occurred in this area, especially near the edges, and in these places, because of the heavy, impervious character of the subsoil, lakes, ponds and marshes were formed and the formation of peat followed. It is mainly in the Wisconsin drift soil area, therefore, that peat occurs in Iowa.* Boone county is located in this soil area and its peat areas, together with muck, make a total of 3,520 acres or 1.0 percent of the total area of the county.

There are two classes of Iowa peat, the shallow and the deep; the latter have been mapped by the Iowa Geological Survey and their commercial value pointed out.** They are composed of fibrous, fairly dry, vegetable matter extending from 5 to 15 feet in depth and they need not be considered from the agricultural standpoint. The shallow peats are usually not over three feet in thickness and the reported experiments on peat soils have dealt only with them, and the results are not at all applicable to deep peats.

The peat in Boone county is generally from 10 to 14 inches in thickness and only in two or three localities does it extend to a depth of more than three feet. Practically all the peat soils may be reclaimed and made productive by proper methods of treatment and cropping.

Analyses of numerous samples of peat soil showed that they contained not only an abundance of nitrogen and organic matter, but also considerable amounts of lime. Their phosphorus and potassium content was rather low, but these elements were abundant in the clay which forms the subsoils of practically all the shallow peats in Iowa. In Boone county there are no areas where the subsoil under the peat is not a black to drab, plastic clay. The character of the subsoil plays a very important part, as will be seen in the

*Bull. 157 Ia. Agr. Exp. Sta.—Improving Iowa's Peat and Alkali Soils.
**Iowa Geological Survey 19: 168, 1908.

treatments which are advised for the reclamation of peat soils. On this account, the heavy character of the subsoils underlying the peats in this county is emphasized.

Field experiments were carried out several years ago on some typical shallow peats near Somers, Eagle Grove and Ontario, in Webster, Wright and Story counties, and these tests were considered at length in bulletin No. 157. The tests included the use of gypsum, limestone, phosphorus and potassium, each applied alone or in combination, in the amounts in which such materials are generally applied to soils. In no cases were there any profitable increases in crop yields from the use of any of these materials and in most instances the variations in yields between the treated and the untreated soils were only such as might easily occur between duplicate plots.

It is apparent from the data given in those field experiments that the shallow peats in Boone county do not need the addition of commercial fertilizing material to make them productive. Altho they are not high in phosphorus and potassium, applications of fertilizers containing these constituents do not seem to be necessary and crops seem able to secure a sufficient amount of these plant foods from the subsoil, which is well supplied with them. Furthermore, peat soils contain an abundance of nitrogen and organic matter and applications of manure are not advisable. Not only is it of no special value, but in many cases it increases the weed growth on the reclaimed peat to such an extent that it is almost impossible to control it. A small application may be of use on newly reclaimed peat by serving to introduce decay bacteria and increase the speed of decomposition.

DRAINAGE AND CULTIVATION FOR PEAT SOILS

What the peats in Boone county need to make them productive is physical improvement thru drainage, cultivation and the growing of proper crops.

Drainage is the most important step. Sufficient tile of ample size and special drains to carry away flood waters and prevent the flooding of the low-lying peat areas at times of heavy rainfall, are essential. The tile in the drainage system should be laid in the underlying subsoil rather than in the peat itself, as in the latter case, the compacting of the peat would bring the tile too close to the surface and re-laying would be necessary. The tile should not be laid too deeply in the subsoil, as the heavy clay is quite impervious. It is often advisable to cover the tile at points a few rods apart with straw, gravel, cinders or some other material which will allow for the ready passage of water into the drains.

Fall plowing is desirable in order to expose the peat soil to the action of the frost, rain and snow during the winter and hasten decay. Fall-plowed peats may be worked earlier in the spring, hence, the seed bed may be more thoroly prepared. Deep plowing is also valuable, especially when the peat is very shallow and some of the underlying, heavy clay, rich in phosphorus and potassium, may be mixed with the peat. The physical and chemical conditions of the peat are both much improved by such a mixing and crop production is increased. Even in the case of deeper peats, where the subsoil is not reached by the plow, it is of advantage to plow to a considerable depth in order to open up the peat to the action of the air and thus hasten decomposition.

Iowa peat soils which are not over sixteen inches in depth should not be rolled, as such an operation may compact them too much and check decomposition. Where the peat is deeper than this, careful rolling may be of value in providing a firmer seed bed, but the practice cannot be generally recommended.

The frequent cultivation of peat soils is very important in opening them up and hastening decay of the organic matter. Furthermore, the growth of weeds is kept in check by cultivation, a fact which is particularly important on newly reclaimed peat, as the weed growth is apt to be luxuriant and interfere seriously with the production of crops.

Corn and small grain crops, as a rule, do not do well on newly reclaimed peat soils. The corn may not mature and the small grains may develop an abundance of straw and little grain. Therefore, it is not advisable to seed these crops on peat soils until several years after their reclamation, when the organic matter has reached an advanced state of decomposition.

A mixture of timothy and alsike clover is probably the best crop to seed on newly reclaimed peat land. It may be cut for hay, but it is better used as pasture, as the trampling by the stock compacts the peat and thus aids in its decomposition. A number of Iowa farmers who have used this crop in this way report a rapid decay of the peat and reclamation within a few years.

Many vegetables have been grown satisfactorily on peat soils. Onions, celery, tomatoes and potatoes all gave excellent results on the experiment plots near Ontario. Cabbages, beets, turnips and other crops might also prove of value. The use of such crops on newly reclaimed peat soils should be encouraged.

After a few years of pasturing or growing truck crops, peat soils are usually in a condition which will permit of the successful growth of corn and small grain crops. When properly reclaimed, peat soils may become extremely productive and it is certainly advisable to attempt the utilization of the peat areas in Boone county. With proper treatment and crop growth, they can be reclaimed.

"ALKALI" SOILS

So-called "alkali" spots may frequently be found on farms located in north central Iowa in the Wisconsin drift soil area. They are mainly associated with peat deposits and vary in size from one-tenth of an acre to two acres.

There are several areas of "alkali" soils in Boone county and while their extent on individual farms is small, they seriously reduce crop yields and present a difficult problem in management.

Such "alkali" spots are characterized by a whitish deposit of salts on the surface of the soil, giving the ground the appearance of having been lightly strewn with a fine white powder. Corn produces only a stunted growth on such spots while other crops are affected to less extent.

The origin of these spots has been discussed in another publication.* They occur in connection with swales, ponds, or sloughs which have recently been drained. They are not found in the lower parts of the slough but always in a belt around the low spot, which frequently consists of peat, and they do not appear until after the area has been drained.

*Bull. 157, Ia. Agr. Exp. Sta.—Improving Iowa's peat and Alkali soils.

The character of the accumulation of so-called "alkali" salts in such localities has been considered in the bulletin mentioned and more in detail in a later publication** and it is apparent from the studies which have been carried out that the salts which occur are quite variable. The chief constituent is calcium bicarbonate, which is carried in solution in the soil water and deposited on the surface as calcium carbonate. Other salts are also common to the Iowa "alkali" soils, magnesium carbonate and bicarbonate of sodium being frequently found. The amount of these latter salts which make up the "alkali" content of the Boone county "alkali" soils, are insufficient alone to cause injury to crops. Their presence, however, with the excess of calcium bicarbonate which always occurs, may prove injurious.

The "alkali" problem in Boone county and in Iowa in general is therefore less serious than in the west and the reclamation is more readily accomplished.

TREATMENT FOR ALKALI SOILS

The first treatment necessary for the reclamation of "alkali" soils in Iowa is proper drainage. "Alkali" spots do not appear until after a soil is drained but this does not mean that the drainage produces the "alkali" conditions. A large amount of salts was present prior to drainage and the excess water merely concealed the high content. Thoro drainage is essential for the removal of "alkali" salts from the soil and in draining a slough or pond lines of tile should be laid around the low area as well as thru the center. These two lines will then run thru the area where the "alkali" is most likely to appear and the washing out of any excess of salts will be more rapid. The lines of tile may be brought together again below the slough and if the area is rather wide, a third line of tile thru the center of the slough may be advisable.

If tile is properly laid when a pond or slough is to be drained, the occurrence of "alkali" spots may frequently be prevented. When the "alkali" spot is fully developed, as is frequently the case in Boone county, the removal of excess salts by proper drainage of the area is hastened considerably by the application of heavy dressings of farm manure. Straw or any kind of vegetable matter plowed under will also aid in the rapid removal of salts. It may be advisable in some cases to sow oats on such ground and when the greatest growth has been attained, plow under the entire crop. Manure, however, has the greatest effect on "alkali" spots and should be used wherever available in sufficient amounts. In other cases green manures, or straw, may serve for the purpose but where such materials are used a small application of manure should be made along with them in order to hasten decomposition processes which in turn hasten the removal of the excess of salts. No other fertilizing constituents are of value in reclaiming "alkali" soils as far as is known. The thoro drainage of the areas and the introduction of an abundance of organic matter are the most effective methods which can be employed.

**Bul. 177, Ia. Agr. Exp. Sta.—The Alkali Soils of Iowa.

THE NEEDS OF BOONE COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The laboratory greenhouse and field experiments which have been described in previous pages have given sufficiently definite results so that general recommendations regarding the treatments needed by the soils of the county may be made. Altho the field tests reported have been carried out in other counties the soil types are the same as those occurring in Boone county, and the results may be considered to indicate quite definitely the effects of the same fertilizer treatments in this county. The recommendations are also based upon the general experience of many farmers and only those suggestions are made which have been shown to be of value by considerable practical experience. It should be emphasized that the recommendtions made are such that they can be put into effect on any farm.

The tests which are suggested are simple and may be carried out readily. Simple fertilizer tests are being made on many farms and the results which are being secured are proving of considerable value to the farmers themselves and also to others located on the same soils. The Soils Section of the Iowa Agricultural Experiment Station will aid any farmers who wish to carry out tests on their own soils. It is desirable to determine the value of both rock phosphate and acid phosphate on small areas before applications are made extensively.

LIMING

The surface soils of Boone county are generally acid in reaction. Occasionally surface samples of the soils of the Webster series show a lime content but in general this is not true. Many of the soils, however, show a considerable amount of lime in the lower soil layers. The Webster silty clay loam, Webster loam and the Clarion soils on the uplands are all well supplied with lime in the subsoil. Similarly one of the terrace soils and the Sarpy silt loam on the bottoms show a lime content in the subsoil. Acidity in the surface soil, however, indicates that in many cases applications of lime may be very desirable and even necessary for the best growth of many crops, particularly legumes. Lime disappears from soils ratherly rapidly depending on the cropping and other conditions in the soil and hence in many of the types in this county the content of lime is decreasing even in the lower soil layers. In order to supply the lime needed in the surface soil for the early growth of crops such as clover and alfalfa and in order to keep up the content of lime permanently in the soil, applications of limestone are evidently necessary. The soils of the Carrington and Conover series and practically all of the terrace types need lime at the present time. Many of the surface soils of the other series would also respond to lime at the present time and this material will certainly be needed in the future.

The addition of lime to soils is of considerable value because of the improvement it brings about in the physical, chemical and bacterial conditions. Heavy soils are made more open and porous and are therefore better aerated and kept from becoming too wet. Light sandy soils are made less porous and more retentive of moisture and plant food and less likely to be injured by drouth.

Chemically, soil is improved by liming because it neutralizes the acidity present in the soil, and if these acids accumulate they may prove highly injurious. The plant food calcium which is required by many plants in considerable quantities is also supplied by the addition of lime. Lime improves the soil also because it increases the development of all beneficial soil bacteria, nitrate production is increased, more nitrogen is fixed and there is a generally greater production of available plant food. In individual cases lime may increase crop yields because of improved physical, chemical or bacterial conditions. But in most cases it seems probable that the beneficial effects of lime are due to the influence on all these conditions.

There is a wide variation in the amount of lime which should be applied to soils. The figures given earlier in this report indicate merely the needs of the particular samples, they do not show the general need of the soil types. Even soils of the same type will not show the same lime requirements and hence it is necessary that tests always be made of the soil in each field before lime is used. Farmers may test their own soils for acidity and need of lime, but in general it is more satisfactory for them to send a small sample to the Soils Section of the Iowa Agricultural Experiment Station and have it tested free of charge.

It is important that lime be applied to many of the Boone county soils and farmers should see to it that the soils are tested and that lime is applied as needed. It is important that such tests be made at regular intervals, as one test and one application of lime will not suffice for all time. It is suggested that the soil be tested at least once in a four-year rotation and preceding the legume crop of the rotation. Lime may then be applied to that crop on which it will show the greatest effect. If the soil is distinctly acid, other fertilizer treatment will prove less valuable and crop yields will not be as satisfactory as when lime is used. Further information regarding the losses of lime from the soil, the requirements of certain crops and other points in connection with liming are given in bulletin 151 of the Iowa Agricultural Experiment Station.

MANURING

Most of the soils in Boone county are not strikingly deficient in organic matter and in fact in some cases there is a very large supply. There is evidence, however, that on rather considerable areas fertilizing materials should be employed to bring up the content of organic matter and on all the soils the supply must also be maintained. Farm manure proves of large value on most of the soil types. In general it seems to be the most profitable fertilizer which can be employed. Furthermore, other fertilizers have less effect if manure is not applied. Only in the case of the Webster soils should precautions be taken in applying manure and on these types it should not be applied to the soil preceding the small grain crop owing to the danger of causing it to lodge. Small amounts may be used on these soils at other points in the rotation, however, with beneficial effects. The value of manure is shown not only on soils which are low in organic matter and light in color but also on the types which are apparently well supplied with this material and dark in color.

Manure exerts a beneficial effect on the soil because of the improvement which it brings about in the physical, chemical and bacterial conditions. Light open soils are made less porous and more retentive of moisture and plant food. Heavy impervious types are opened up and better aerated. Plant food constitutents are supplied to the soil in manure and it serves therefore to return to the land much of the fertility removed by the crops grown and used as feed. It is of large value in lengthening the life of the soil or delaying the time when the essential elements will become deficient. Large amounts of organic matter are also supplied in manure giving a further chemical effect on the soil. Manure contains enormous numbers of bacteria and these organisms when introduced into the soil with the manure bring about a very large increase in the production of available plant food.

On many farms the manure produced is not properly cared for and large losses of valuable constitutents occur before the material is applied to the soil. Too often it is considered a waste product to be disposed of with the least amount of difficulty. Losses occurring from manure improperly stored may be very large. In some cases as much as 90 per cent of the valuable portion of the manure has been found to be removed when it was allowed to stand in uncovered heaps exposed to the weather and the liquid portion allowed to leach away. When manure undergoes loss by leaching or improper fermentation the value for increasing crop growth is very much reduced. The losses, therefore, mean actual decreases in crop yields. When carefully stored and applied to the soil manure may return 75 to 80 percent of the plant food constituents removed by the crops grown. It may be stored in a covered yard or pit or protected from losses in some other manner. No one method of handling can be recommended, as conditions vary so widely on individual farms. But in general any method which will keep the manure moist and compact and protected from the weather, will prove satisfactory. Any reasonable expense involved is always well warranted by the increased crop yields secured from its use.

The amount of manure which is applied to soils varies considerably. In general eight to ten tons per acre is applied once in a four year rotation. On the average farm larger applications than this are not possible as the production of manure even on the livestock farms is restricted and it is rarely that all the land on the farm can be treated regularly with manure. The material is applied to one area and very often other areas on the farm are neglected. Even when larger amounts of manure are available for use it would not be desirable to apply more than 16 to 20 tons for ordinary farm crops. In truck farming larger applications are sometimes employed with profit. On the heavy Webster soils in Boone county small applications may yield a profitable return if not made just preceding the small grain crop. Large amounts should not be employed on such soil types.

On many livestock farms there is an insufficient production of manure to meet the needs of the soil for organic matter. And on the grain farm some other material must be employed to supply organic matter. In both cases green manuring is the practice which is recommended. Legumes are considered the most desirable for use as green manures inasmuch as they have the ability, when well inoculated, of utilizing the nitrogen present in the

atmosphere. Thus when they are turned under in the soil they not only supply organic matter but also add considerable nitrogen. Occasionally non-legumes are employed as green manures but it is very seldom that their use is desirable. There are many legumes which can be used as green manures and it is possible therefore, to choose one which will fit in with almost any crop rotation or system of farming under particular soil and climatic conditions.

Green manuring may be practiced advantageously in some cases in Boone county. The practice should not be followed carelessly nor blindly however, as it may lead to undesirable effects under certain conditions. If the soil is too dry for example, the green material will not be decomposed and will not have a desirable effect on the soil and indeed may even prove injurious. The Soils Section will make suggestions in regard to green manuring under special conditions on request. Occasionally the second crop of clover is turned under in the soil and this provides for a partial green manuring crop. Frequently the clover seed is removed and the remainder of the crop plowed under. This also provides considerable green manuring effect. Occasionally the legume may be seeded in the corn with the last cultivation and the entire crop turned under.

A thoro utilization of all crop residues such as straw and stover is of considerable importance in keeping up the organic matter supply in the soil. If these materials are burned or otherwise destroyed as so often happens considerable value is lost. They contain much organic matter and also considerable amounts of fertility constituents and hence are of double value when turned under in the soil. On the livestock farm they are often stored and allowed to decompose at least partially before application. This is a desirable practice. Under both systems of farming, however, it is important that all the crop residues be utilized in keeping up the organic matter supply. By the proper use of these residues, the careful preservation of all farm manure produced and the utilization of leguminous crops as green manure it is possible to keep up the organic matter content in soils and insure satisfactory crop yields.

THE USE OF COMMERCIAL FERTILIZERS

The soils of Boone county in general are not particularly well supplied with phosphorus and phosphorus fertilizers will certainly be needed in the future and may be of value in many cases at present. The greenhouse and field experiments described earlier in this report indicate rather definitely that certain phosphorus carriers may yield profitable returns on some of the more extensive soil types. It is certainly desirable that farmers test the application of a phosphorus fertilizer to a small area and thus determine whether or not the same fertilizer should be applied to a large area.

The analyses reported in an earlier section of this report show the total phosphorus content of the soils. These figures do not show, however, how much of the element is in a form available for plant use. A high content of phosphorus does not necessarily mean a satisfactory supply of available phosphorus to plants. On the other hand a low content of phosphorus is

a good indication that there is a lack of a proper production of this element in available form and that there is a need for a phosphorus fertilizer. Hence even on those soils in Boone county which seem to be better supplied with phosphorus the application of a phosphate fertilizer might prove distinctly profitable.

Rock phosphate and acid phosphate are the two phosphorus fertilizers which are most generally employed agriculturally. Rock phosphate is slowly available in soils and must be applied in rather large amounts. Acid phosphate carries the phosphorus in an available form but it is more expensive. Smaller applications of this material may, however, be made. The field experiments in this county and thruout the state include tests of both these materials. Evidence is not sufficiently definite as yet however to permit of a choice being made between these two phosphates for use on Boone county soils. It frequently happens that one material appears more desirable in one experiment but this may not necessarily be true in a similar test under somewhat different conditions. It is evidently most desirable that farmers test both materials on their own soils if they are to determine with any degree of accuracy which fertilizer will give them the best returns. The actual crop increases secured and the value of the increases compared with the cost of the fertilizer treatments show quite definitely whether phosphorus in one or the other form will give results and which form is the most desirable. Simple field tests of these materials can be carried out on any farm and farmers may thus secure results of value for their own conditions and also aid in the solution of the problem in general. Directions for the carrying out of such field tests on the farm are given in circular 82 of the Iowa Agricultural Experiment Station.

The nitrogen content of Boone county soils is not strikingly low in any of the soils but in many of the types the supply is not particularly high. Only the Webster soils on the upland and the Wabash types on the bottomland are high in the constituent. Continued crop production on these soils will remove nitrogen from the soils and it is evident that the supply of nitrogen is not sufficient on any of the soils to provide for crop production for an unlimited period. Some means must eventually be employed to keep up the supply and in several of the types it would be very desirable to increase the content in this element at the present time.

Farm manure and leguminous green manures are the cheapest and best sources of nitrogen for use on soils. When the manure produced on the livestock farm is carefully stored and returned to the land there is a considerably less rapid decrease in nitrogen content. On the grain farm leguminous green manures serve a similar purpose, in many cases not only keeping up the nitrogen content but actually increasing the supply. Whenever there is insufficient production of manure, green manuring is a desirable practice. If a proper rotation is practiced a legume is included and when this legume is well inoculated there may be considerable addition of nitrogen to the soil. If the crop is entirely removed from the land however no nitrogen will be added, and if the legume is grown without inoculation there will be no benefit to the soil. It is essential that thoro inoculation of the crop be accomplished and that it be handled in such a way that there be at least a partial return of the green

material. If the seed only of the legume is removed and the remainder of the crop plowed under there may be a very considerable addition of nitrogen to the soil. Sometimes legumes are seeded as catch crops and then the entire crop is plowed under to increase the nitrogen and organic matter content of the soil.

Crop residues return to the land some of the nitrogen removed by crops and the proper utilization of these materials is very important in keeping up the supply of nitrogen in the soil. These materials with farm manure and leguminous green manures are the natural nitrogenous fertilizers and they are most commonly and successfully used in building up and maintaining the nitrogen supply of the soil.

Occasionally commercial nitrogenous fertilizers are used in small amounts as top dressings to stimulate the early growth of certain crops. Their use is not desirable, however, on general farm crops and they are not recommended to be used unless tests on small areas have shown profitable results. In general leguminous green manures, farm manures and crop residues serve quite adequately to keep up the nitrogen in soils.

Earlier analysis of many of the soils of the state have shown a high content of potassium in practically all cases. The soils of Boone county are apparently well supplied with this constituent and it would seem hardly likely that potassium fertilizers would give profitable results if used on general farm crops. If there is an inadequate production of available potassium, however, it may be desirable to apply a small amount of the muriate or sulphate of potassium. Small applications of these materials especially if applied as top dressings stimulate the earlier growth of some crops. It is believed, however, that if the soil is kept in good physical condition and well supplied with organic matter, thoroly drained and aerated, there should be a sufficiently rapid production of available potassium to supply plant needs. Applications of potassium fertilizers are being made in some of the field tests which are under way thruout the state in order to learn whether or not the use of such materials may be profitable. At the present it can merely be recommended that farmers who are interested test the value of potassium carriers on their own soils, making tests on small areas before using the fertilizers in any extensive way.

Complete commercial fertilizers are being tested in the field experiments thruout the state and their value is being compared with that of the phosphorus carriers. Complete fertilizers are more expensive than the phosphorus fertilizers and hence they must bring about very much larger results in crop yields if they are to prove profitable. The experiments reported earlier and many other tests not referred to in these pages have not shown any superiority for complete fertilizers over acid phosphate. There is no objection to the use of complete commercial fertilizers if they prove profitable, but farmers should test the material on small areas and compare the results secured with the phosphorus carriers if they are to reach definite conclusions as to the value of extensive application. In general it seems that the phosphorus fertilizers are more valuable. Wherever truck crops are grown, however, complete brands might be used more successfully.

DRAINAGE

Much of the area of Boone county is quite adequately drained. There are areas, however, where artificial drainage is desirable and even necessary. The sketch map given earlier in the report indicates the extent of the natural drainage system in the county and it will be noted that in many areas there is a scarcity of intermittent drainage lines. The level areas of Webster loam and part of the Webster silty clay loam are generally very poorly drained. The other upland soils are usually well drained. Most of the terrace types show adequate drainage and the Wabash soils on the bottoms are of course inadequately drained. Wherever a soil is too wet crop production is decreased considerably. The installation of tile is a very desirable practice on the Webster types in this county and may be necessary in local areas of some of the other types. Even if the expense involved is rather considerable the returns secured more than warrant the outlay. No other treatment will prove satisfactory if the soil is not thoroly drained and fertilizer additions should not be made until the soil is well drained.

ROTATION OF CROPS

The proper rotaton of crops is very essential if the fertility of the soil is to be maintained. Soils become rapidly depleted in fertility if one crop is grown continuously on land and it becomes an increasingly difficult matter to build them up again. Even if the crop grown is a money crop the value of all the crops produced on the area over a period of years will be greater when a rotation is practiced. Too much emphasis cannot be placed upon the importance of adopting a proper rotation on every farm, and farmers should appreciate the fact that the growing of one crop continuously will make their land very rapidly lower and lower in productive power.

Many satisfactory rotations can be used for all conditions. Some of these rotations which are very satisfactory are suggested below. In all of the proposed rotations where clover is designated it is understood that the crop may be red, alsike, sweet or Hubam clover. Various modifications in these rotations may be made as necessary.

1. SIX-YEAR ROTATION

First year—Corn
Second year—Corn
Third year—Wheat or oats (with clover, or clover and grass)
Fourth year—Clover, or clover and grass
Fifth year—Wheat (with clover), or grass and clover
Sixth year—Clover, or clover and grass

2. FOUR OR FIVE-YEAR ROTATION

First year—Corn
Second year—Corn
Third year—Wheat or oats (with clover or with clover and timothy)
Fourth year—Clover (If timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy)

3. FOUR-YEAR ROTATION WITH ALFALFA

First year—Corn
Second year—Oats
Third year—Clover
Fourth year—Wheat
Fifth year—Alfalfa (The crop may remain on the land five years. This field should then be used for the four year rotation outlined above and the alfalfa shifted to one of the fields which previously was in the four-year system.)

4. FOUR-YEAR ROTATIONS

First year—Wheat (with clover)
Second year—Corn
Third year—Oats (with clover)
Fourth year—Clover

First year—Corn
Second year—Wheat or oats (with clover)
Third year—Clover
Fourth year—Wheat (with clover)

First year—Wheat (with clover)
Second year—Clover
Third year—Corn
Fourth year—Oats (with clover)

5. THREE-YEAR ROTATIONS

First year—Corn
Second year—Oats or Wheat (with clover seeded in the grain)
Third year—Clover (In grain farming, only the grain and clover seed should be sold; most of the crop residues such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil and only the seed taken from the second crop.)

First year—Corn
Second year—Oats or wheat (with clover)
Third year—Clover

First year—Wheat (with clover)
Second year—Corn
Third year—Cowpeas or soybeans

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or the "lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much of the soil may be carried away in this manner to the detriment of the land.

Light, open soils which absorb water readily are not apt to be subject to erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is effected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion while land in sod is not effected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action.

The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manure, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil may be exposed and the crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but it is less harmful and is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

Erosion occurs to some extent in Boone county, affecting particularly the steep phase of the Clarion loam. This soil is frequently very badly washed. There are areas in the Carrington loam also which are injured by erosion. Whenever serious washing of the land occurs and gullies are formed it is most desirable that some means be taken to prevent the loss of fertility from the soil.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings as applicable to "dead furrows," to small gullies, to large gullies, to bottoms and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle with it, frequently result in the formation of gullies.

"Plowing In"—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In"—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists in driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series

should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point upstream. Additional brush may also be placed above the stakes, with the tops pointing upstream, permitting the water to filter thru, but holding the fine soil.

Earth Dams.—Earth dams consist of mounds of soil placed at intervals along the slope. They are made somewhat higher than the surrounding land and act in much the same way as the stakes in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them; that takes much work and is not lasting.

Checking Overfalls.—The formation of small gullies or ditches is practically always the result of overfalls and one of the most important problems is, therefore, the checking of these overfalls and preventing them from working back and extending the size of the gully. An easy method of checking the overfalls is to put in an obstruction of straw and brush and stake down with a post. One or more posts should be set firmly in the ground in the bottom of the gully. Brush is intertwined between the posts, straw is well tramped down behind them and the straw and brush both are held in place by cross pieces nailed to the posts. This method does not fill the existing ditch but does prove very satisfactory for preventing the overfall from working back upstream. It is an installation which is very desirable before any success can be had in filling small or large gullies.

"Staking In."—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the staking in operation recommended for the control of dead furrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush-pile, or hooked over one of the main stems and driven well into the ground. Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water. A series of these brushpiles may be installed up the course of the gully and with the regular repair of washouts or undercuttings may prove very effective.

The modification of this system of "staking in" which is being used with success in some sections, consists in covering the bottom and sides of the ditch with straw for a distance of four to ten feet, depending upon the width of the

ditch. Brush, ranging in size from fine at the bottom to coarse at the top, is laid on the straw with the butts headed upstream. The brush and straw are held in place by cross pieces spiked to posts previously set. The number of posts will depend of course upon the size of the gully. These posts should be set well into the ground and spaced about four feet apart, being arranged in a V-shape with the point downstream and lower in the center than at the sides of the ditch. This modification of the "staking in" method is proving very satisfactory.

The Straw Dam.—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving of time, labor and inspection.

The Earth Dam.—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam.—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T," called the surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass.

The Adams Dam—This dam is practicallly the same as the Christopher or Dickey dam. In fact the principle of construction is identical. In some sections the name "Adams Dam" has been applied and hence it is mentioned separately. This is one of the most satisfactory methods of filling gullies and the dam may also serve as a bridge. The installation of a culvert is generally made of sewer tile with tightly cemented joints and it is recommended that the inlet to the tile be protected from clogging by the installation of posts supporting woven wire. The concrete or plank spill platform is a very important feature of the Adams dam and it is also recommended that an

up-stream concrete guard be constructed so that the face of the dam is protected. Taking into account the cost, maintenance, permanence and efficiency, the Adams dam or the Cristopher or Dickey dam may be considered as the most satisfactory for filling ditches and gullies, especially the larger gullies.

The Stone or Rubble Dam—Where stones abound they may be frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage—The removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to a depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies which are often called ravines may in general be controlled by the same methods as in the case of small gullies. The Christopher or Adams dam, already described, is especially applicable in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such low-lying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and tiling.—The straightening of the larger streams in bottomland areas may be accomplished by the community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

Trees.—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are in-

terfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Sod Strips.—The use of narrow strips of sod is very desirable for preventing hillside erosion as well as for the preventing of gully formation. The sod protects the field from the flow of water during rains and prevents the washing away of the surface soil.

Deep Plowing.—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil therefore, reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN BOONE COUNTY[1] [2]

The individual soil types in the county are grouped into three groups according to their origin and location. These are drift soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are six drift soils in the county and these with the steep phase of the Clarion loam make seven drift soil areas. Together they cover 93.3 percent of the total area of the county. They are classified in the Carrington, Clarion, Webster and Conover series.

CARRINGTON LOAM (1)

The Carrington loam is the most extensive soil type in the county, covering 40.4 percent of the total area. It occurs in all parts of the county, being confined mainly to the rolling to strongly rolling land bordering the creeks and smaller streams. The largest areas are found along Beaver creek, southeast of Boone and in Peoples township. The various areas thruout the county

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[1]The descriptions given in this section of the report very closely follow those in the Bureau of Soils Report.

[2]Boone county adjoins Webster and Hamilton counties on the north and Polk county on the south. In the certain cases the maps of the counties do not appear to agree along the boundaries. This is due mainly to changes in correlation resulting from a fuller understanding of the soils of the state. The type mapped Miami silt loam in Webster county is now correlated with the Conover series. The Webster clay loam of Hamilton and Polk counties, on account of its small area, has not been mapped in Boone but has been included with the Webster silty clay loam. For the same reason the Lamoure silty clay loam of Polk county has, in this area, being included with the Wabash loam. (Bureau of Soils Report.)

Fig. 4. Carrington loam topography in Boone county.

are quite generally cut into small individual areas by narrow areas of soils of the Webster series or by relatively inextensive areas of Clarion soils. There are no large individual areas of the Carrington loam anywhere in the county.

The surface soil of the type is a brown mellow loam, 14 to 18 inches in depth. The subsoil is a brownish-yellow to yellowish-brown sandy clay loam to sandy clay, occasionally showing some mottlings of gray in the lower depths. In some areas the lower subsoil is gritty and contains some gravel and sand. In the more rolling areas along some of the creeks, the surface soil is shallower and lighter in color than the typical soil. Along the Hamilton county line in the northeastern part of the county, the topography is more rolling and the surface soil is a lighter brown loam than the typical approaching a fine sandy loam in texture and the subsoil is a friable sandy clay, grading into the gravelly glacial till at 30 to 34 inches. On the tops of hills and sharp knolls the surface soil is often thin and yellowish-brown in color, due to the erosion which has occurred. Thruout many of the less rolling areas between the streams, the surface soil is darker in color than typical and the subsoil is mottled with brown and yellow.

On account of their small extent, some areas of fine sandy loam have been mapped with this type. These areas are found on isolated hills and ridges, the largest occurring in the vicinity of Pilot Mound and Mackey. There are also two small areas of this sandy soil east of Beaver. The surface soil in these areas is a brown, fine sandy loam, eight to ten inches in depth, resting on a yellowish-brown heavy fine sandy loam or clay loam subsoil.

The topography of the Carrington loam varies from undulating to strongly rolling. The drainage of the type in general is quite satisfactory. In the more rolling areas, there is no need for artificial drainage and only occasional-

ly in the more level areas where the type is associated with the Clarion soils, is it necessary to tile out the land.

Practically all of the soil is under cultivation. The few belts of native trees on the steeper slopes along the streams and the windbreaks surrounding many farm dwellings are the only forested areas.

All the general farm crops are grown in the county, corn occupying the largest acreage, with oats second and hay third. Corn yields 35 to 65 bushels per acre; oats, 38 to 60 bushels; wheat, 12 to 28 bushels; barley, 18 to 35 bushels and hay, 1 to 2 tons. Practically all of the corn and oats and all of the hay produced on the farms are fed to the hogs, cattle and work stock, the surplus corn and oats being sold to the local elevators and shipped out of the county. Some of the corn crop is utilized for ensilage, and soybeans are often planted with it when it is to be used for this purpose. Rape is sometimes grown in the corn and used for hog pasture. Alfalfa is grown on some areas and excellent results are being secured. Wheat, barley and rye are grown to some extent and used for feeding purposes.

The Carrington loam is naturally a very fertile soil and crop yields are generally quite satisfactory. The soil contains considerable organic matter and is fairly well supplied with nitrogen and phosphorus. The latter constituent is not present in an available form in suffcient amounts to keep crops supplied in all cases, and the soil will often respond to applications of phosphorus fertilizers.

The experiments reported in previous pages of this report show quite definitely the possibility of securing profitable returns when phosphorus is applied to the soil. Both acid phosphate and rock phosphate are employed in the field tests and sometimes one material proves more desirable while in other cases the other seems to be the better for use. Definite recommendations cannot be made at the present time and it is recommended that farmers test the need of phosphorus on their own soils and at the same time determine which phosphorus fertilizer will yield the better results. This may be done by the carrying out of simple tests on the farm on small areas. Applications of these materials to large areas are not recommended until tests on small areas have shown them to be of value.

The soil is apt to be acid in reaction and lime should be added in amounts shown to be necessary according to tests. The soil should always be tested before growing legumes such as alfalfa or red clover and lime should be used, if the soil is acid, in order to insure the best growth of the crop.

While the type is not strikingly deficient in organic matter, the application of farm manure or leguminous green manures is very necessary for the maintenance of permanent fertility and may also be of distinct value in increasing crop yields at the present time.

Farm manure often gives very considerable increases in crops as will be noted in the experiments described earlier in this report and its use is very desirable on this soil. Livestock farmers should see to it that all the manure produced on their farms is properly stored and applied to their soils. It is a most valuable fertilizer and its application regularly will aid materially in keeping the soils permanently productive. There are probably cases also where the use of leguminous crops as green manures would be very desirable, especially

when there is no farm manure produced. If legumes are employed as green manures or at least a part of the crop is utilized for green manuring purposes, then it is possible to keep up the nitrogen content of the soil as well as the organic matter supply.

By the proper use of farm manure or the turning under of green manures, by the application of a phosphorus fertilizer, and by the use of lime when needed, crop yields may be increased in many instances on this soil and it may be kept permanently productive. Occasionally it may be desirable to improve the drainage conditions of local areas, and it is always necessary to tile in such cases.

CLARION LOAM (138)

The typical Clarion loam is the third largest soil type in the county but with the steep phase, which is smaller in area, it makes up however, the second largest area, amounting to 20.1 percent of the county.

It occurs in all parts of the county, chiefly in small areas, in association with the Carrington loam and the Webster soils. The largest areas are found west of the Des Moines river and in the vicinity of Madrid, the most extensive individual areas occurring along Beaver creek in the southern part and in the extreme northwestern part. In many of the areas the type occupies an intermediate position between the level Webster soils and the more strongly rolling areas of the Carrington loam.

The surface soil of the Clarion loam is a brown to very dark brown or black mellow, friable loam, 15 to 18 inches in depth. The subsoil is a yellowish-brown to grayish-brown friable clay loam, grading at 28 to 30 inches into a yellowish-gray or mottled gray, brown and yellow clay loam or clay. In the more level areas the soil is blacker in color due to the higher content of organic matter. In the lower subsoil in many places there are gray mottlings and occasionally there is a gray layer. This gray coloration of the subsoil is caused by the high content of lime which is characteristic of the Clarion soils. In the eastern half and southern part of the western half of the county the calcareous layer is deeper than in the typical soil and in many places is just within the 3-foot section.

Just west of Ogden and near Angus and Berkley the surface soil is a brown to dark brown loam underlaid by a yellowish-brown friable clay loam mottled with gray below 30 inches. Where the calcareous layer is very deep in the soil section the type approaches the Carrington loam in characteristics and the boundaries are arbitrarily drawn in many cases. There are included within the type several small areas of Clarion fine sandy loam and Carrington loam and fine sandy loam too small to separate on the map.

In topography the Clarion loam is gently undulating to rolling and the drainage is generally quite adequate. In a few locations where the type is closely associated with the Webster soils the installation of tile might occasionally be necessary but in most of the areas the drainage conditions are excellent.

The Clarion loam is practically all in cultivated land or in pastures. The only forested areas are the windbreaks which have been set out near farm buildings. Corn, oats and hay are the principal crops grown, corn occupying the largest acreage. Wheat, barley and rye are also produced on small areas

Fig. 5. Valley of the Des Moines river near Moingona.

and some alfalfa, rape and sorghum are grown. Some surplus of corn and oats over the demands for these crops for feeding purposes on the farms, is sold at the local elevators and shipped out of the county. All the hay which consists mainly of timothy and clover mixed, is used for feed. The wheat and barley are mainly fed on the farms, only a small surplus being sold. Rye is used principally for spring pasturage. Alfalfa is not grown very extensively but it proves a profitable crop and its use is to be encouraged. Rape is grown mainly for hog pasture.

The crop yields of the various crops grown in the county are quite satisfactory. Corn yields 35 to 70 bushels per acre; oats 35 to 50 bushels; wheat, 15 to 18 bushels; barley, 20 to 35 bushels; and hay 1 to 2 tons per acre. Under the most desirable conditions from the soil and seasonal standpoints, the corn yields may amount to 80 to 90 bushels and the oats to 60 to 70 bushels per acre.

The Clarion loam is naturally a productive soil but crop yields may often be improved by the adoption of proper methods of soil treatment. The phosphorus supply is not high and there is evidence that the application of a phosphorus fertilizer might often be distinctly profitable. Farmers are urged to test the effect of acid phosphate and rock phosphate on their own soils by means of simple tests and thus determine whether their soils need phosphorus and which material will be the most desirable.

The soil is not particularly low in nitrogen or organic matter but these materials must be kept up in the soil for continued fertility and it is very desirable therefore that farm manure be applied to the soil regularly and in the usual amounts and that legumes be used at least partially as green manures

if the future yields of crops is to be satisfactory. Actually it has been found in practice that farm manure will give considerable increases in crops at the present time. Where farm manure is not available for use, it is particularly desirable to use legumes as green manures.

If the soil is acid as is frequently the case in the surface soil, the application of a small amount of limestone as shown to be necessary according to the tests will permit of the best growth of legumes. The soil may be subject to some washing in some areas and when that is the case, some method of protecting it from serious losses should be adopted. If the drainage is inadequate in any cases, then tiling will be of value.

CLARION LOAM, STEEP PHASE (151)

The steep phase of the Clarion loam occupies about one-half as large an area as the typical soil, covering 6.8 percent of total area of the county. It occurs mainly along the steep slopes of the Des Moines river and some of the tributary streams. There is a small area along Squaw creek. There are no large continuous areas of the soil but it occurs in many narrow strips separating the Carrington or Conover soils of the uplands from the bottoms.

The surface soil of the steep phase Clarion loam is a brown to dark grayish-brown loam, 7 to 12 inches in depth. The subsoil is a yellowish-brown to brownish-yellow clay, mottled with gray and brown and calcareous in the lower part of the 3-foot section. On the steeper slopes, the washing away of the surface soil has been so complete that yellowish clay is frequently exposed at the surface.

Along the lower slopes the soil is deeper owing to the wash from above and the soil is darker in color. In many places along the Des Moines river, especially between Sixteen-to-One bridge and New bridge, the surface soil is a lighter brown to grayish-brown in color. In a few areas the subsoil contains much fine gravel and in other places beds of gravel have been exposed by erosion.

In topography this phase is steep to precipitous. Drainage is good and may even be excessive in some few areas. The soil is not of much agricultural significance. The greater part of it is in forest, consisting mostly of red oak, bur oak, bass wood, maple, hickory and some walnut. Where the slopes are not thickly forested, blue grass grows well and makes excellent pasture. A few of the more gentle slopes are cultivated, and corn, oats and wheat are the principal crops grown. Apples and small fruits such as strawberries, raspberries and gooseberries are also grown to some extent. The yields of these various crops are very much the same as those secured on the typical soil. In these cultivated areas, the response to fertilizer treatments will be very much the same as noted for the Clarion loam. In general much of the phase should not be cultivated and is of the most use when left in pasture. The need for protection from erosion is of course very evident in all areas.

WEBSTER LOAM (55)

The Webster loam is the third most extensive soil type in the county, covering 16.3 percent of the total area. It occurs in all parts of the county in association with the more rolling Carrington and Clarion soils on the uplands,

Fig. 6. Morainic hills on Webster loam.

and also with the heavier textured silty clay loam of the Webster series. The largest individual areas of the type occur in the northwestern part of the county altho there are numerous rather extensive areas just east of the Des Moines river. Most of the areas are small and occur scattered thruout the uplands.

The surface soil of the Webster loam is a very dark brown to black mellow loam, 16 to 18 inches in depth. The subsoil is a grayish-brown to dark drab silty clay to clay, mottled with gray, brown and yellow. In some of the more level areas, the soil is a heavy loam, approaching a clay loam or silty clay loam and the subsoil is more mottled. In a few areas, particularly north of Madrid the surface soil is a dark brown to black loam, passing at 18 to 20 inches into a darker brown to dark drab heavy loam, which at about 30 inches grades into a gray to grayish-brown silty clay. Small areas of silty clay loam and silt loam, too small to show on the map are included with this soil.

The topography of this type varies from level to gently undulating to gently rolling. The drainage of the soil in general is quite inadequate and in many areas the first treatment needed to make the soil productive is the installation of tile and the removal of excessive moisture.

Practically all of the Webster loam is under cultivation. Corn occupies the largest acreage, oats is second in importance and wheat, barley and rye are of relatively minor value. Corn yields 40 to 65 bushels per acre; oats, 70 to 90 bushels and other crops give correspondingly good yields. Under the best conditions, when the soil is well drained, corn may yield from 70 to 90 bushels. Some sorghum is grown for making sirup and on some areas rape is grown for hog pasture.

The Webster loam is chiefly in need of thoro drainage, if it is to be made as highly productive as possible. It is very necessary that the tile be laid properly in this soil if the removal of water is to be as rapid as desirable. Sufficient fall for the outlets of the drains must be provided and more laterals are needed than in soils where the subsoil is not so impervious. Often the tile is too small and the main drains do not carry away the water as rapidly as desirable. After drainage has been accomplished, deeper plowing and the use of proper crop rotations will permit of good crop yields. Phosphorus fertilizers may be of value in some cases and these materials should be tested. Small applications of farm manure may be made on newly drained areas with beneficial results but manure should not be applied to this soil just preceding the small grain crop of the rotation owing to the danger of causing it to lodge.

For maintaining permanent fertility in this soil some manure should be applied at regular intervals and the legume crop of the rotation should be utilized in such a way that there will be some addition of organic matter and nitrogen to the soil, phosphorus fertilizers must be used and eventually lime will be needed, altho it is rarely needed at the present time.

WEBSTER SILTY CLAY LOAM (107)

The Webster silty clay loam is the fourth most extensive soil type in the county, covering 11.1 percent of the total area. It occurs in all parts of the county in small, more or less isolated bodies. It is found principally in the lower, flatter areas along the intermittent drainageways and in the depressed level sections of the uplands. There are numerous very small areas, some very narrow, marking by their location the lowest areas of the intermittent drainage lines. There are no large individual areas of the type. It is associated closely with the Carrington and Clarion soils of the more rolling uplands and with the level Webster loam.

The surface soil of the type is a black silty clay loam, 10 to 12 inches in depth. The subsoil is a dark brown to grayish-brown silty clay loam to silty clay to a depth of 20 to 24 inches. Below that point it becomes a grayish-brown to dark drab tenacious silty clay to clay mottled with brown, gray and yellow. In the more poorly drained areas there is a high content of lime in the surface soil, and the lower subsoil is always rich in calcareous material. There are included with the type a few small areas of Webster loam and clay loam too small to show on the map.

The Webster silty clay loam varies in topography from level to very gently undulating. The natural drainage of the soil is quite inadequate and the installation of ditches and tile drains is very necessary if this land is to be used for general farm crops and yields are to be at all satisfactory in average seasons. The first treatment needed by the type is usually better drainage. In some instances where attempts have been made to bring about drainage, sufficient tile has not been used or it has not been properly laid and the soil still suffers because of a lack of proper moisture conditions.

About 75 percent of the type is now under cultivation, the principal crops being corn and oats. Some hay is grown and small areas are devoted to wheat,

Fig. 7. Webster silty clay loam showing alkali spots in the foreground.

barley and rye, with some flax. The low poorly drained areas support a good growth of natural grasses, which are used for hay. Corn yields 38 to 55 bushels per acre; oats, 35 to 70 bushels, and hay, 1½ to 2½ tons per acre. Oats have a tendency to lodge but when the Iowa 103 and Iowa 105 varieties are used and the seasonal conditions are satisfactory, yields of this crop are quite satisfactory.

The chief need of this soil type to make it more productive is the thoro drainage of such areas as are still inadequately tiled out. When this is accomplished, then the yields of general farm crops are quite satisfactory. There is no excessive amount of phosphorus present in the soil and there is a possibility therefore that the soil, may respond to applications of phosphorus fertilizers. Tests of these materials on small areas are very desirable. Small amounts of farm manure may be applied to newly drained areas with value but it is not desirable to apply any large amounts, and manure should not be used just preceding the small grain crop of the rotation. The regular use of farm manure and the proper method of handling the legume crop of the rotation are necessary if the fertility of the soil is to be kept up indefinitely. Phosphorus fertilizers will undoubtedly be necessary in the near future if they do not seem to be needed at the present time and eventually lime will be needed altho now the soil is high in lime.

CONOVER SILT LOAM (167)

The Conover silt loam is of minor importance in the county, covering only 4.9 percent of the total area. It is confined to narrow strips of level to undulating land bordering the Des Moines river and the larger tributary streams. The most extensive areas occur on the east side of the river just west of Boone

Fig. 8. Conover silt loam topography.

and south of Hull school. The strips vary in width from an eighth of a mile to a mile. The areas are most extensive on the east side of the river. They are quite generally separated from the bottoms by the steep phase Clarion loam.

The surface soil of the Conover silt loam is a gray to light grayish-brown floury silt loam, 6 to 8 inches in depth. The subsoil to a depth of 18 to 20 inches is a yellowish-gray to grayish-brown compact clay loam, mottled with gray, brown and yellow. Below that point, it becomes a yellow, grayish-yellow or mottled gray, brown and yellow, tough, compact, gritty clay. When dry the surface soil is light gray and floury. When wet it appears darker colored. At the lower depths there is more sand and gravel and the lower subsoil is more friable than the upper layers. Boundaries are often difficult to draw between this soil and the darker colored upland types.

Originally the Conover silt loam was in forest but the major portion has now been brought under cultivation. The remaining tree growth consists of white oak, red oak, hickory, ash, elm, maple, and some walnut. Corn, oats, wheat and clover are the main crops grown, corn being the most extensively grown. Barley, rape, millet, rye and timothy are also grown to some extent. Most of the crops grown are utilized for feeding purposes on the farms. The surplus is sold and shipped out of the county. The yields of the general farm crops are very much the same as those secured on the poorer areas of the Carrington loam. The average yields are lower than the average yields obtained on the Carrington and Clarion soils.

This soil could be made much more productive by proper methods of handling the soil. In the first place it needs liberal additions of organic matter. Farm manure should be applied in as large amounts as are possible and if

farm manure is not available for use, then leguminous crops should be employed as green manures. Deeper plowing would be of considerable advantage and should be practiced along with the use of manure. The soil is acid and the use of lime is very necessary for the best growth of legumes. The addition of phosphorus fertilizers would also undoubtedly prove profitable. Tests of phosphorus carriers are recommended.

CLARION FINE SANDY LOAM (149)

The Clarion fine sandy loam is a very minor type in the county, covering only 0.5 percent of the total area. It occurs entirely in the northeastern part of the county on the tops of knolls and ridges. The largest area is just south of the Hamilton county line in the extreme northwestern corner of Harrison township.

The surface soil of the Clarion fine sandy loam is a dark brown fine sandy loam to a depth of 8 to 12 inches. The subsoil is a yellowish-brown fine sandy loam to sandy clay loam, mottled or streaked with gray below 30 inches. The lower subsoil contains considerable calcareous material. On the tops of the sharper knolls the surface soil is not so deep owing to the erosion which has occurred. The soil is lighter in color in these places also, ranging from a light brown to a pale yellowish-brown, and the glacial material is found in the 3-foot section. The gray color in the subsoil is more pronounced owing to the higher content of lime. Within the type there are included several small areas of Carrington loam and Clarion loam, too small to show separately on the map.

The topography of the Clarion fine sandy loam is rolling to strongly rolling. The drainage of the type is good to excessive. Practically all of the type is under cultivation or in pasture. The only forest growth is a few willows along the fence rows and windbreaks which have been set out on the farms. General farm crops are grown but the yields are somewhat lower than on the heavier upland types with which it is associated.

The type is low in organic matter and would respond particularly to applications of farm manure and large applications of this material are strongly recommended. If farm manure is not available for use it is very desirable that leguminous crops be used for green manures, in order to build up the soil in organic matter and nitrogen. It is not acid in reaction and in fact contains considerable lime in the subsoil but the surface soil may be somewhat acid and when that is the case, then lime should be applied if the best growth of legumes is to be secured. The type is low in phosphorus and applications of phosphorus fertilizers would undoubtedly give profitable returns. Tests of these materials are recommended.

TERRACE SOILS

There are six terrace soils in the county, belonging to the Buckner, Waukesha and O'Neill series. Together they cover 1.9 percent of the total area.

BUCKNER LOAM (38)

The Buckner loam is the most extensive terrace soil in the county, covering however only a small area, amounting to 0.6 percent of the total. It occurs only on the terraces along the Des Moines river, being developed in narrow strips adjoining the bottoms. The largest areas occur just north of Moingona.

The surface soil of the Buckner loam is a dark brown to black mellow loam, 18 to 20 inches in depth. The subsoil is a lighter brown to yellowish-brown loam to fine sandy loam. There is very little difference between the surface soil and the subsoil in many areas, little change in color or texture occurring in the 3-foot section. Near Fraser the soil has a light brown color and the texture is almost a fine sandy loam. There are included with the type small areas of fine sand and fine sandy loam, too small to separate on the map.

The Buckner loam is located on terraces, 20 to 40 feet above the normal level of the river and beyond overflow. The topography varies from level to gently undulating. The greater part of the type is cultivated, only a small area being in forest. Corn is the principal crop grown. Some oats are grown but not very extensively. Sorghum is grown for syrup and melons and garden truck in general do well.

The yields of crops on this type are lower than on the upland types and it may be made more productive by better methods of soil treatment. It will respond profitably to applications of farm manure and this material should be used in as large amounts as practicable. Leguminous green manures are also very desirable for use in many cases. Phosphorus fertilizers will undoubtedly prove of value and the addition of lime is necessary if legumes are to be successfully grown.

WAUKESHA LOAM (60)

The Waukesha loam is the second largest terrace soil in the county, covering 0.4 percent of the total area. It is found on the terraces along the Des Moines river and Beaver creek. The largest areas are located in bends of the river, 1 and 2 miles south of the Webster county line and just across the river from Logansport. The areas along Beaver creek are all small, and with the exception of the areas mentioned, the type is confined to relatively small areas.

The surface soil of the Waukesha loam is a brown to dark brown mellow friable loam, 14 to 16 inches in depth. The subsoil is a yellowish-brown sandy clay loam to sandy clay. In some areas the surface soil is higher in organic matter and blacker in color. In the lower part of the three foot section there are occasionally some faint mottlings of gray. In the area just north of New Bridge and across the river from Logansport, the texture approaches a fine sandy loam. In three of the smaller areas along the Des Moines river, the largest being west of Madrid, the soil is quite silty. To a depth of 14 to 18 inches, the surface soil is a dark brown mellow silt loam and the subsoil is a yellow-brown clay loam. Included with the type there are also a few small areas of fine sand and fine sandy loam.

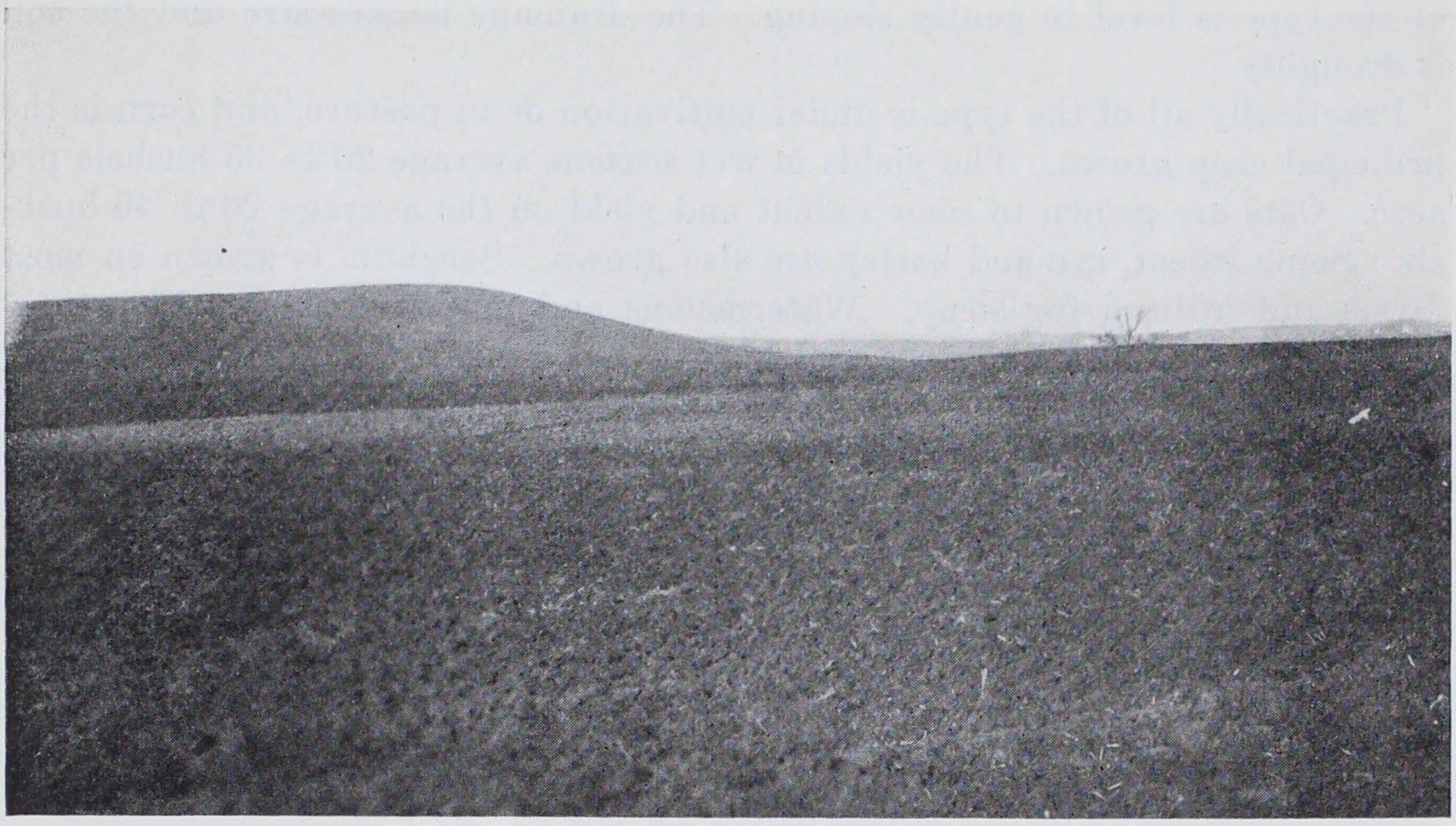

Fig. 9. Morainic area in northeastern part of county. Webster silty clay in foreground.

The Waukesha loam occurs on the terraces well above overflow, and the drainage is quite adequate. Practically all of it is under cultivation. The only timber is a few butternut, walnut and oak trees along the border of some fields. Corn is the principal crop. Some wheat is grown and other farm crops are produced to a limited extent.

The yields of crops on this type are quite satisfactory, being about the same as on the Carrington and Clarion uplands. The soil will respond to applications of farm manure, however, and this material should be applied. Green manuring might also be practiced with value in many cases. The soil is acid and in need of lime and applications of phosphorus fertilizers would also probably be of value. Tests of these materials are very desirable.

O'NEILL FINE SANDY LOAM (110)

The O'Neill fine sandy loam is a minor type in the county, covering 0.4 percent of the total area. It occurs in several small areas along the Des Moines river and Beaver and Squaw creeks. The largest areas are just south of the Webster county line, along the Des Moines river. None of the areas are at all extensive.

The surface soil of the type is a brown to dark brown to nearly black fine sandy loam, 7 to 9 inches in depth. The subsoil is a light brown to yellowish-brown fine sandy loam, grading at 22 to 26 inches into a yellow fine sand or loamy fine sand. In a few areas the surface soil is comparatively shallow and the subsoil grades into a loose bed of sand and gravel at 18 to 20 inches. There are included with the type small areas of the loam which are too small to be shown on the map.

The O'Neill fine sandy loam is located on terraces, 40 to 60 feet above the normal level of the river and 10 to 15 feet above that of the creeks. It is above overflow, except under very abnormal flooding conditions. The topography

of the type is level to gently sloping. The drainage is excessive and the soil is droughty.

Practically all of the type is under cultivation or in pasture, and corn is the principal crop grown. The yields in wet seasons average 20 to 35 bushels per acre. Oats are grown to some extent and yield on the average 20 to 40 bushels. Some wheat, rye and barley are also grown. Sorghum is grown on most farms and utilized for sirup. Watermelons and muskmelons are frequently grown and do well. Potatoes and garden truck prove very satisfactory on this type.

Crop yields on the O'Neill fine sandy loam may be increased quite considerably by proper methods of soil treatment. The application of farm manure gives large effects and this material is very desirable for use. Leguminous crops as green manures are also to be recommended in order to build up the soil in organic matter and nitrogen. It is acid in reaction and in need of lime. It is low in phosphorus and would undoubtedly respond to applications of phosphorus fertilizers.

O'NEILL LOAM (108)

The O'Neill loam is a very minor type in the county, covering only 0.2 percent of the total area. It occurs on the terraces along the Des Moines river and Beaver and Squaw creeks. The largest areas are found in the bends of the river 2 miles southwest of Boone and just west of Sixteen-to-One bridge. The areas are all rather small and scattered however, and the type is relatively unimportant.

The surface soil of the O'Neill loam is a dark brown to almost black light textured loam, 8 to 10 inches in depth. The subsoil is a light brown to yellowish-brown sandy clay loam, grading at 20 to 23 inches into a sticky sand or gravel layer. Included with the type there are a few small areas of O'Neill fine sandy loam too small to show separately on the map.

The topography of the type is level to gently sloping. Drainage is apt to be excessive and crops suffer in dry seasons. Practically all of it is under cultivation or used as pasture. The principal crops are corn and oats. Wheat, barley, rye and sorghum are also grown to some extent. Garden truck and potatoes are raised on a small scale for home use. The yields of corn amount to 20 to 40 bushels per acre in wet years and oats yield 28 to 43 bushels. In dry seasons the yields are very low.

This soil is in need of organic matter principally, in order to make it more retentive of moisture and more productive. Applications of farm manure are very necessary and legumes turned under as green manure will also give good results. The soil is acid and in need of lime for the best growth of legumes. It will also undoubtedly respond to applications of phosphorus fertilizers.

BUCKNER SILT LOAM (36)

The Buckner silt loam is a minor type in the county, covering only 0.2 percent of the total area. It occurs on the terraces along the Des Moines river. None of the individual areas are at all extensive, the largest occurring near Sixteen-to-One bridge, south of Boone.

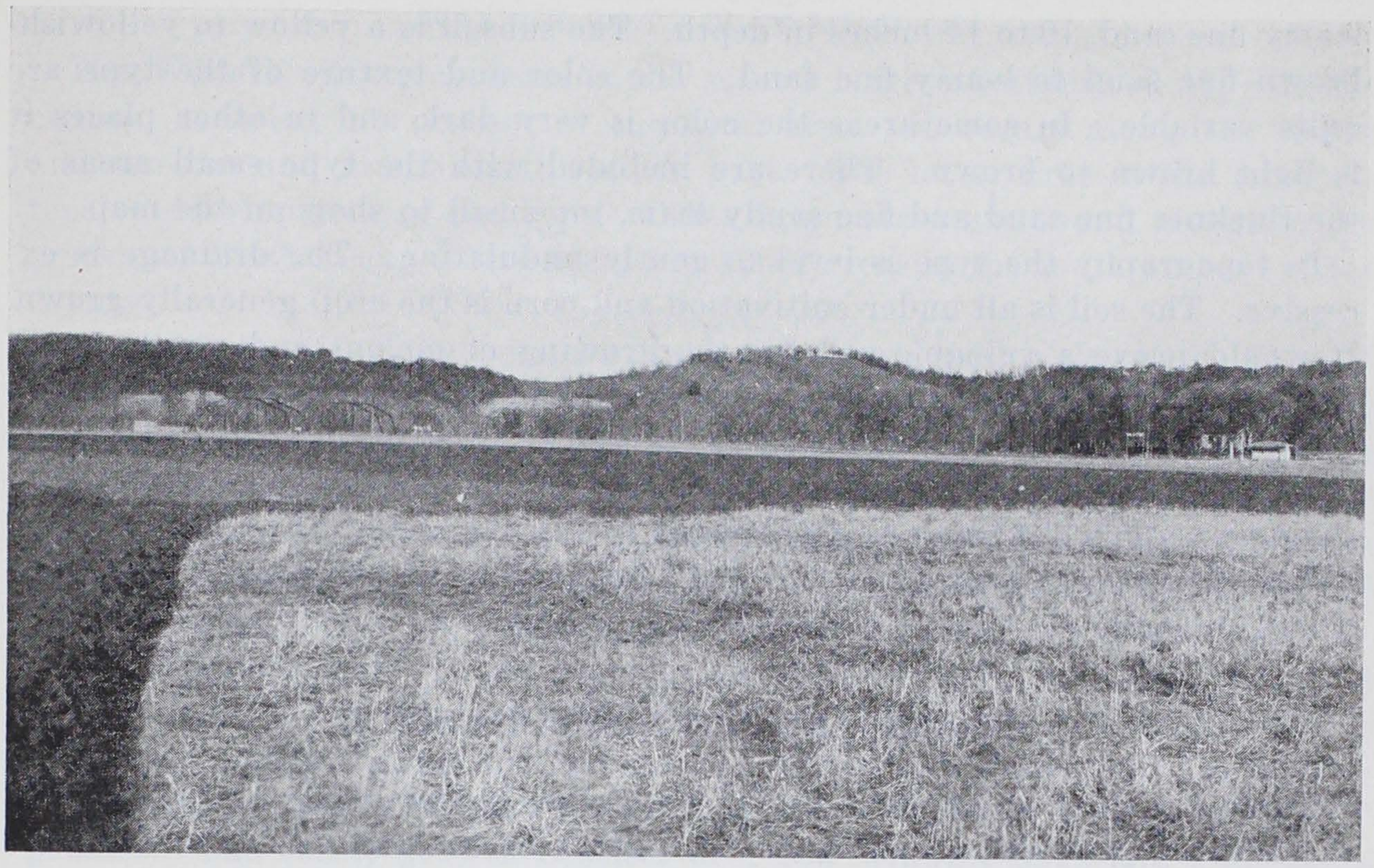

Fig. 10. Buckner silt loam on terrace. Bluffs in background.

The surface soil of the type is a very dark brown to black silt loam, extending to a depth of 18 to 20 inches. The subsoil is a light brown to brown silt loam. In many of the areas the subsoil is very much the same as the surface soil, there being very little change in color or texture to a depth of three feet. There are some small areas of the loam included with the type, owing to their small extent.

The Buckner silt loam lies about 20 to 30 feet above the normal level of the river, and from 2 to 8 feet above the first bottoms. The topography is gently sloping and the drainage conditions are quite satisfactory.

The type is practically all under cultivation. Corn is the chief crop with oats and hay second in importance. Wheat and rye are grown in some areas. Corn yields 35 to 70 bushels per acre, oats, 36 to 60 bushels, and hay, 1½ to 2 tons.

This soil is generally quite highly productive but it will respond to proper methods of soil treatment. Farm manure gives large effects on crop growth and leguminous green manures might be used in some cases to advantage. The type is acid in reaction and should be limed if the best growth of legumes is to be secured. The application of phosphorus fertilizers would probably prove beneficial and tests of these materials are recommended.

BUCKNER LOAMY FINE SAND (168)

The Buckner loamy fine sand is of very minor importance in the county, covering only 0.1 percent of the total area. It occurs in narrow strips on the terraces of the Des Moines river, the largest area being found in the bend of the river, just west of Boone. It is usually formed as a low dike-like ridge on the outer edge of the terrace.

The surface soil of the Buckner loamy fine sand is a brown to dark brown

loamy fine sand, 10 to 14 inches in depth. The subsoil is a yellow to yellowish-brown fine sand to loamy fine sand. The color and texture of the type are quite variable. In some areas the color is very dark and in other places it is light brown to brown. There are included with the type small areas of the Buckner fine sand and fine sandy loam, too small to show on the map.

In topography the type is level to gently undulating. The drainage is excessive. The soil is all under cultivation and corn is the crop generally grown. It would prove a valuable soil for the growing of melons and potatoes. It is low in organic matter and should receive liberal applications of farm manure or legumes should be turned under in the soil in order to build up the content of organic matter and nitrogen. It is acid in reaction in general and lime should be applied whenever it is needed.

The phosphorus content is low and applications of phosphorus fertilizers would undoubtedly prove of value in many cases.

SWAMP AND BOTTOMLAND SOILS

There are three swamp and bottomland types in the county and these with the area of peat and muck make four areas of bottomland. The soils are classified in the Wabash and Sarpy series.

WABASH LOAM (49)

The Wabash loam is the most extensive bottomland type, covering 1.9 percent of the total area of the county. It occurs on the first bottoms along the creeks and smaller streams in the eastern half and in the southwestern corner of the county. The largest areas are found along Beaver creek and Big creek. All the areas are narrow, and vary from 50 feet to one-fourth of a mile in width.

The surface soil of the type is a very dark brown to black friable loam, 14 to 16 inches in depth. The subsoil is a dark drab to dark gray clay, mottled with gray and brown. The black color often extends to the depth of three feet, the soil being particularly high in organic matter in these areas. There are many variations in both color and texture in the soil. Sometimes the surface soil is a heavy black loam 15 to 18 inches in depth, underlaid by a drab or gray silty clay mottled with rusty brown. Occasionally the black loam grades at 18 to 20 inches into a black silt loam which may extend to a depth of three feet or change into a drab silty clay at 30 to 34 inches.

The type is flat or slopes gently toward the streams. It is subject to overflow and the drainage is poor. Only a small part is cultivated, most of the areas being in grass and pasture. The only tree growth is a few willows along the streams and fence rows and an occasional elm, oak or ash. Hay is the principal crop, the yield averaging 1½ to 2 tons per acre.

If this soil is to be cultivated and brought under a crop rotation, it would need first of all to be protected from overflow in order to insure crop growth. It is poorly drained and should be tiled out. It is acid in reaction and would need lime. The content of organic matter is not low but applications of farm manure would be of value if used in small amounts on newly drained areas. The application of phosphorus fertilizers would also probably prove of value.

WABASH SILTY CLAY LOAM (48)

The Wabash silty clay loam is the second largest bottomland type in the county, covering 1.1 percent of the total area. It occurs along the creeks and streams and in the northwestern part. The latter area is the most extensive development of the type. Other large areas are found along Beaver creek and Bluff creek. There are a few small areas in the southern part of the county.

The surface soil of the type is a black silty clay loam to clay loam, 14 to 16 inches in depth. The subsoil is a black to a very dark gray silty clay with faint brown mottlings and iron stains in the lower depths. In some areas the surface soil for a few inches is a silt loam or heavy loam. The subsoil often grades at 30 to 34 inches into a dark gray plastic clay mottled with rusty brown and dull yellow. There are included with the type small areas of loam and silt loam which were too small to show on the map.

The type is located on the bottoms, generally about 2 to 4 feet above the normal level of the streams and it is subject to overflow. In topography it is level to gently sloping and the natural drainage is inadequate. It is practically all utilized for pasture and supports a luxuriant growth of native grasses. The forest growth consists of a few willows, oaks and elms along the streams.

Where the soil has been included with adjacent areas under cultivation the yields of corn and other crops are good. If the drainage conditions were improved and the soil were protected from overflow, it would prove a good agricultural soil. It would then need to be treated with farm manure, limed and supplied with phosphorus fertilizers in order to make it as highly productive as possible and also to keep it fertile.

PEAT AND MUCK (21)

There are numerous small areas of peat and muck scattered thruout the county, together making up 1.0 percent of the total area. These areas occur in basin-like areas in the uplands where ponded conditions have formerly existed and water loving grasses have grown in profusion and have decayed. The largest bodies are found in the northwestern part of the county. The areas vary in size from a few acres to 80 acres. Some areas are so small that they could not be shown on the map.

Peat consists of a brown, dark brown or almost black mass of partly decomposed vegetation mixed with some mineral matter washed in from the surrounding land. The organic matter ranges from 6 to 30 inches in depth, averaging about 20 inches. It is underlaid by a black or dark drab silty clay or fine sandy clay. The material is spongy and porous and occasionally quite fibrous. It is black when wet. It is high in lime content. Thru cultivation the peat has been decomposed and mixed with the black silty clay brought up from the subsoil and the peaty character of the soil is fast disappearing and the soil is becoming a silt loam or a silty clay loam. Within the areas of peat there are included some areas of muck. This is a black mass of well decomposed plant remains mixed with considerable mineral matter. It is derived from the decomposition of peat. It ranges in depth from 8 to 20 inches and is underlaid by a black to drab silty clay to clay.

The treatments needed for the reclamation of peat and muck areas have been discussed earlier in this report and need not be repeated here.

SARPY SILT LOAM (89)

The Sarpy silt loam is a very minor type in the county, covering 0.8 percent of the total area. It occurs in narrow strips along the Des Moines river, most of the areas occurring in the southern part of the county.

The surface soil of the type is a gray to brownish-gray silt loam, 8 to 12 inches in depth, underlaid by a gray loamy fine sand. At 18 to 20 inches this grades into a brownish-gray to brown fine sandy loam. Both soil and subsoil are high in lime content. In places the intermediate layer of loamy fine sand is absent and the surface soil rests directly on the heavy fine sandy loam. In other areas the silt loam extends to a depth of 3 feet without change in color or texture. Occasionally the subsoil is composed of silt, fine sand and medium sand varying in thickness from 2 to 10 inches. Included with the type there are areas of fine sandy loam which were too small to show on the map.

The type is subject to overflow and the drainage is poor. The greater part is under cultivation. Corn and hay are the principal crops grown. The uncultivated portion supports a growth of oak, maple, elm, willow and some hickory and walnut. Crop yields are very good on cultivated areas when they are not injured by overflow. The first treatment needed is to protect the soil from overflow. It should then receive liberal applications of farm manure or legumes should be turned under as green manures in order to build it up in organic matter and nitrogen. It would also probably respond to applications of phosphorus fertilizers, and tests of these materials would be very desirable.

APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment

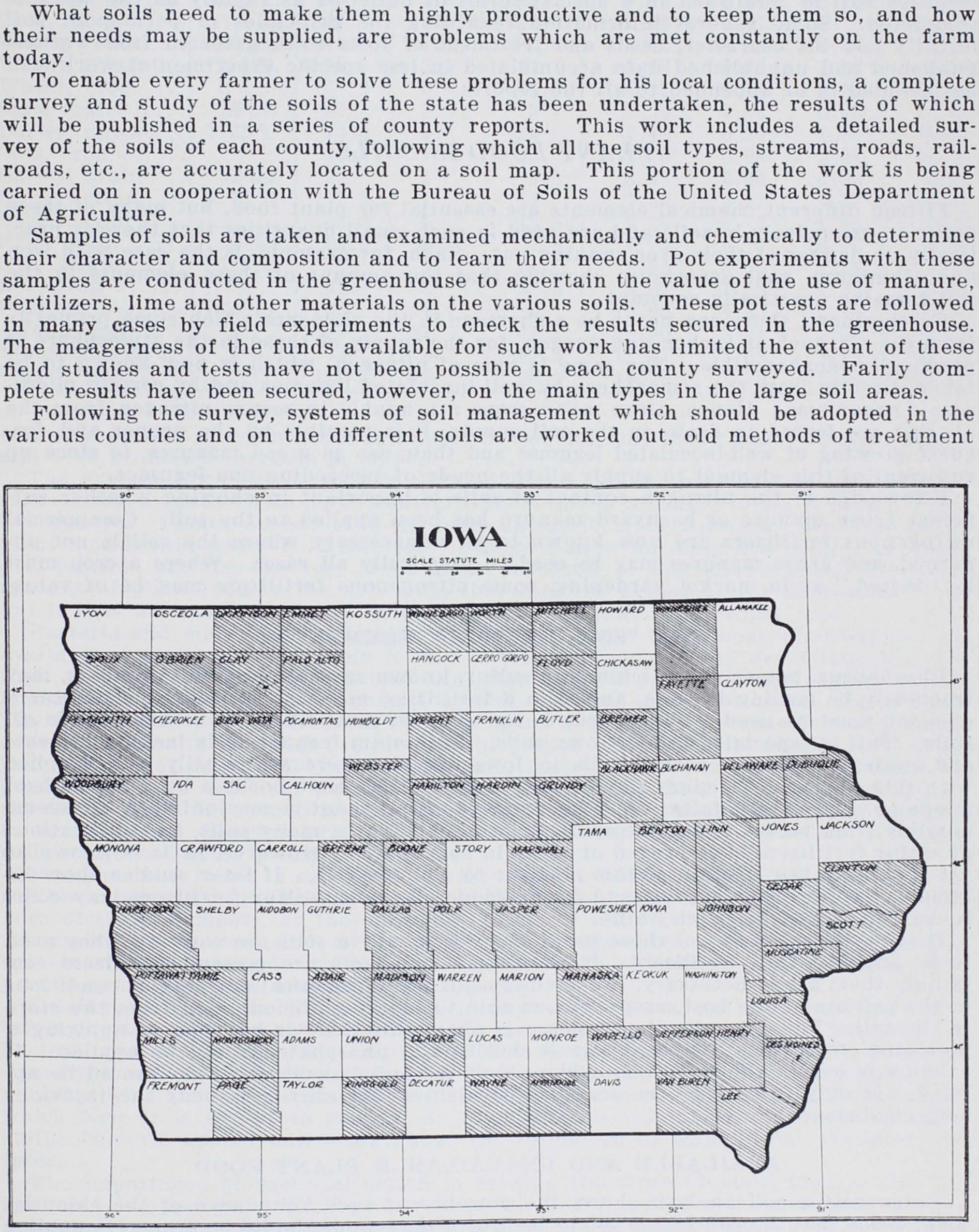

Fig. 11. Map of Iowa showing the counties surveyed.

are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and to insure the best crop production.

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year being determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accumulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOOD IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organisms. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced," as in market gardening, some nitrogenous fertilizers may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil derived" elements, may frequestly be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true of Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage of this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proved of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, applications of a fertilizer containing one of the

TABLE I. PLANT FOOD IN CROPS AND VALUE

Calculating Nitrogen (N) at 16c (Sodium Nitrate (Na NO^3)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant food, lbs.			Value of plant food			Total value of plant food
		Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium	
Corn, grain.....	75 bu.	75	12.75	14	$12.00	$1.52	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	.....	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw ...	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	.....	57.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Barley, straw ...	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	.....	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain ...	30 bu.	23	5	5.5	3.68	0.60	0.33	4.61
Barley, straw ...	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	.....	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain.....	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.5 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	.....	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.25	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy, hay ...	3 T.	72	9	67.5	11.52	1.08	3.95	16.55
Clover, hay.....	3 T.	120	15	90	19.20	1.80	5.40	16.40

elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analysis to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion, but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon doixide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in the soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are

to be properly nourished, care should always be taken that the soil is in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, altho there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elemments are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included, as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the elements in nitrate of soda; phosphorus at 12 cents, the cost in acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growth of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated as they should be, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in non-leguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply may be kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil, there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds at least in the case of constituents which must be replaced at the present time.

Of course, if the crops procured are fed on the farm and the manure carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 percent of the corn and 35 to 40 percent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

This loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported, revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in

the soil for the growth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until the crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for soil production, largely because they help control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for lack of water necessary to bring them their food and also for lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available plant food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during the periods of drouth by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of heavy drouth may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotation. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under, they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same

crop, but have no effect on certain other crops. In a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 per cent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crops residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated and thus increase the nitrogen content of the soil which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated or by the use of inoculating materials that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is possible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and

straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exceptions to the general rule, as was shown by the tests of many representative soils reported in Bulletin No. 151 of this station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin No. 151, referred to above.

As to the amount of lime needed for acid soils as a general rule sufficient should be applied to neutralize the acidity in the surface soil and then an additional amount of one or two tons per acre.

SOIL AREAS IN IOWA

There are five large soil divisions in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 12.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by the great continental ice sheets. These great masses of ice moved slowly over the land, crashing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders of "nigger heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain

large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stone. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause little concern.

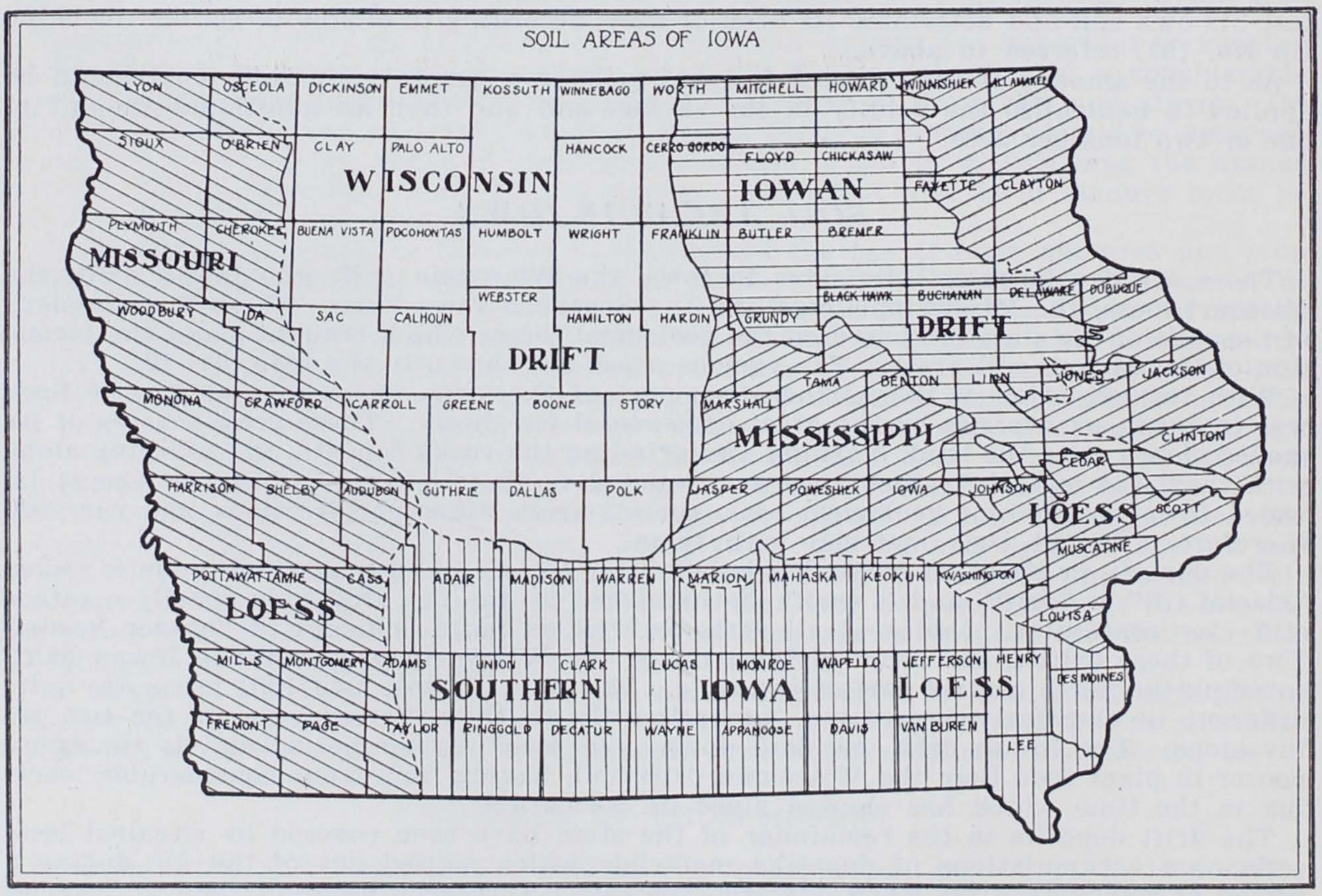

Fig. 12. Map showing principal soil areas in Iowa.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Experiment Station in its Soil Report No. 1.
They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter { All partially destroyed or decomposed vegetable and animal material.

Inorganic matter {
- Stones—over 32 mm.*
- Gravel—32—2.0 mm.
- Very coarse sand—2.0—1.0 mm.
- Coarse sand—1.0—0.5 mm.
- Medium sand—0.5—0.25 mm.
- Fine sand—0.25—0.10 mm.
- Very fine sand—0.10—0.05 mm.
- Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying the soils.

As has been indicated the completed map is intended to show the accurate location and boundaries, not only of all soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of

*25 mm. equals 1 in. †Bureau of Soils Book.

the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by placing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspection and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps of field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed may, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.